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General Editor: H. C. Long, I.S.O., B.SC. (Agric. Edin.)

SUPPRESSION OF WEEDS BY FERTILIZERS AND CHEMICALS

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BY

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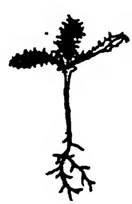

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Foreword

For many years now the destruction of weeds by the application of some chemical has been occupying the attention of investigators, and one material after another has been recommended for practical use. Little by little information has accumulated and as some of the methods have proved their value the time is opportune for their serious consideration by farmers. In the old days freedom from weeds was the mark of a good farmer, and it may be agreed that in most cases skilful cultivation will maintain the land in a clean condition. But with the relative increase in the cost of labour as compared with prices for the produce of the farm the old elaborate cultivation is no longer economic ; the reduction of crop caused by the weeds is less expensive than the cost of extra cultivation required to eradicate them. Unfortunately, when neglect of this kind is forced upon the farmer his trouble increases from year to year, and he must turn to any cheap methods that science can offer in place of the old and well-tried operations of cleaning. The value of the chemical methods is emphasized by the fact that the dearness of labour has brought about a widespread simplification of the old rotations, which has generally taken the form of eliminating or greatly reducing the root crops, one function of which was to clean the land.

There is no lack of chemical substances which will kill any weed with which they are in contact, but as weeds grow mixed up with the crop, at first sight it would seem to be impossible to find any material which would pick out the weeds and be harmless to the valuable plants. However, another factor comes into play ; there is generally a marked difference between the habit of growth and the nature of the leaf surface of the weeds and the crops. More particularly the cereals in the young state possess upright leaves which are not easily wetted. Consequently an application of some substance injurious to all green tissue will rest upon the flat leaves or the rosette that, for

example, young Charlock plants present, and will slide off the early growth of barley or oats. It is on this principle that most of the chemical methods for weed destruction depend.

We may distinguish three types of action in the chemical attack upon weeds.

In certain cases it is necessary to deal with the soil itself, for there are a few weeds which are only troublesome under particular soil conditions that can be rectified. For example, Spurrey is confined to acid soils and on sandy soils lacking lime may accumulate to the pitch of smothering any corn crop that is sown. The only remedy is lime, whereby to reduce the acidity of the soil until it becomes no longer favourable to the growth of Spurrey.

Other weed destroyers depend for their action upon continued contact with the growing plant tissue. Any soluble salt, even if not poisonous in itself, will destroy a green leaf if left upon it, merely because it has so much greater attraction for water than the contents of the plant's cells that it continually withdraws water from them to the point of death. Sulphate of ammonia is a plant food, not a poison, yet a few grains of sulphate of ammonia placed upon the crown of a Daisy or Plantain will scorch it up, and if left long enough will kill the whole plant. Many of the weed destroyers depend upon this sort of action, and even if the injury does not proceed far enough to kill the weeds they are so weakened that the crop gets possession of the land and keeps them under.

The third class embraces substances which possess a definite toxic effect upon the plant independently of the scorching action. Some of them, like sodium chlorate, may be of service to deal individually with the larger weeds, like the Creeping Thistle, which regenerate themselves by an underground root system that is protected from direct attack.

The applications of these principles are dealt with by Mr. Long in the little book that follows. Mr. Long has been at great pains to sift the voluminous literature which is scattered through many periodicals, foreign as well as English. He has put the data into practical form and provided references for those who wish to consult the original papers. Farmers will be well advised to consider whether some of the methods cannot

profitably be adopted in their practice, remembering always the wisdom of trying the process on a small scale first, for local conditions may have no little influence on the results. Whatever measure of success may attend the chemical treatment of weeds, and it is considerable, it can never absolve the farmer from the traditional system of cleaning the land by well-timed cultivations under the rotations that are followed.

March, 1934.

Author's Preface

Most of us may appreciate the beauty of many species of weeds, but regard weeds generally as a nuisance in our crops, and we want to be rid of them. The more easily and cheaply they can be destroyed the better we are pleased. Much has been written about them; indeed, I must plead guilty to having probably dealt more fully with them in books, articles and lectures than any other inhabitant of Britain! From the earliest days of the written word about farming—and doubtless long ere that—the need to destroy weeds has been recognised, and various methods of bringing about the desired end have been described. The story of the first Adam having been told "cursed is the ground for thy sake; in sorrow shalt thou eat of it all the days of thy life; thorns also and thistles shall it bring forth to thee; . . . . in the sweat of thy face shalt thou eat bread," clearly outlines the combat with nature.

The position, however, has since been greatly modified. The gradual evolution of machinery, the rotation of crops, and the development of modern science have tended to reduce manual labour to a minimum—though there is always plenty for those who love crops and stock. Most true farmers, perhaps, also—so far from eating of the products of the soil in sorrow—find their greatest happiness in producing crops in the face of difficulties. Thus is brought nearer the fulfilment of the promise under a later dispensation: "Instead of the thorn shall come up the fig tree, and instead of the brier shall come up the myrtle tree." Anyhow, next to the spiritual struggle, the combat with nature is the greatest of all combats, and the most strengthening.

During the last hundred years much has been learnt about the value of chemical manures in aiding crops to overcome plants natural to the soil—weeds. Since the beginning of the present century we have been learning steadily that certain of these fertilizers and some pure chemicals have a direct action

in destroying specific weeds. It is the purpose of this brochure to place before farmers a simple summary of the more important facts about this subject that may be of value to them in relation to weed destruction. The method of destruction will, of course, depend upon the crop, the quantity and nature of the weeds, the climatic conditions at the time, and sometimes the water supply.

It gives me great pleasure to acknowledge my indebtedness and gratitude to the many who have been of such real help in the preparation of the following pages—to Dr. Winifred Brenchley (Rothamsted Experimental Station), who has ably and heartily collaborated by making herself substantially responsible for sections 4, 7, 8, 10 and 11 ; to Messrs. Alan Whatham, M.A., W. Gavin, C.B.E., and L. D. Martin, M.A., for illustrations, suggestions, guidance and encouragement, all invaluable ; to a number of farmers and others who were so good as to provide information, acknowledged in the text ; to Sir John Russell, Messrs. G. A. Cowie, M.A., B.Sc., H. W. Gardner, B.A., and F. A. Pearson for permission to reproduce photographs, each acknowledged in its place ; and my colleague, Mr. A. B. Worn, who was good enough to read over the proofs. Finally, I desire to record my very cordial thanks to Sir Daniel Hall for so kindly introducing my pages to those for whose help they have been prepared.

For any suggestions, for fresh information, and for friendly criticism, I shall be sincerely grateful.

H. C. LONG.

Surbiton,
March, 1934.

Note to Second Edition

A great deal of research on this subject has been done since this book was first published, and a revised edition is long overdue. With the generous care and assistance of Dr. Winifred Brenchley, who has been responsible for most of the revision, this new edition has now been prepared, with the inclusion of fresh chapters and extra illustrations. For various suggestions I am much indebted to Professor K. W. Braid, Dr. E. Wyllie-Fenton, Professor G. E. Blackman, and Mr. A. E. Sell (Imperial Chemical Industries) : while Rothamsted Experimental Station, Imperial Chemical Industries, Mr. S. F. Armstrong, and others have supplied photographs.

Many of the materials discussed or recommended in this volume are at present in short supply, or may be unobtainable, but with the happy cessation of hostilities we can hope for a return to conditions that will enable the trade to make reasonable provision for our needs.

Extensive investigations into chemical weed destruction were undertaken in 1945 with the aid of funds provided by the Agricultural Research Council. Since this revised edition of this volume was prepared a report on the investigations has been published and is reproduced with all due acknowledgments by permission of the Ministry of Agriculture and Fisheries and H.M. Stationery Office. (See Appendix, p. 74).

H. C. LONG.

Esher,

May, 1946.

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I.—Losses Due to Weed Infestation

In a general way farmers and gardeners are well aware of the injury that is done to their crops by the presence of an excessive quantity of weeds. Knowing as much as they do about the relationship of weeds to crop yields, however, farmers can nevertheless scarcely do better than give an hour's careful thought to the manner in which the damage is done. It has been described many times.

In both arable and grass land, weeds exert pressure upon man's cultivated crops, and in several directions at once. The weeds occupy space that is needed by the crop for fuller growth ; they absorb and transpire large quantities of water that ought to be available for the crop ; they steal plant food specially provided for the crop ; they deprive the crop of air, sunlight and heat ; they make cultivations, " singling " of root crops and harvesting operations more difficult ; they harbour injurious insects and fungi of many species ; some of them are parasitic and suck the juices of the " host " crop ; quite a number are poisonous ; underground growths may choke drains ; the presence of weed seeds reduces the value of seed crops of all kinds.

In short, weeds cause greatly increased labour costs, and reduce crop yields—so bringing about money losses in both directions. The loss of crop is frequently 40 to 50 per cent., and sometimes a crop may be a total failure owing to weed infestation. In the autumn of 1933, the farm manager of a big estate observed that if they could not kill the Wild Radish in a field sown to winter oats there would be no crop in 1934 ; and he was accordingly prepared to risk severe injury to the oats, or even re-seeding, in an endeavour to destroy the weed. Times are very difficult, and low prices were the vital factor in the agricultural depression of 1934, but even at existing prices let the farmer figure out for himself the difference between a barley crop of 18 cwt. per acre and one of 6½ cwt. ; between a potato crop of 175 cwt. and one of 90 cwt. ; between a 45-bus. crop of oats and one of 67 bus., or one of 24.8 bus. and one

of 76.5 bus.; and between a mangold crop of 16¼ tons on a weedy plot and 37¼ tons on a plot hoed twice (after singling). The figures represent actual results as between clean and weedy plots of the same crops.

So costly are weeds found in New Zealand that in 1930 the sum of £2,000 was allocated by the Empire Marketing Board for weed control research in that Dominion.

Finally it is officially recorded that it was estimated before the Great War of 1914-18 that about 16½ millions sterling per annum were lost by farmers in Great Britain in growing (and getting rid of) weeds ; and it is certain that owing to the higher cost of labour, seeds, etc., this figure must undoubtedly be now much increased.

Korsmo's work* in Norway has demonstrated the injury that may be done by weeds, and the increases in crop that may be obtained by their destruction. The following table embodies certain figures showing average increases in yield with many experiments during the years 1916-23 :—

AVERAGE INCREASES IN YIELD DUE TO TREATMENT, COMPARED WITH UNTREATED CROP.

Treatment	Spring Wheat		Barley		Oats		Spring Cereals as a Whole		
	No. of Expts.	Incr. in grain %	No. of Expts.	Incr. in grain %	No. of Expts.	Incr. in grain %	No. of Expts.	Incr. in Crop Grain %	Incr. in Crop Straw %
Harrowed before germination of the cereals ...	63	8.1	188	12.3	159	8.1	420	10.2	2.5
Harrowed before and after germination of the cereals	33	6.3	103	21.1	80	10.7	223	15.8	6.1
Sprayed with solution of iron sulphate ...	95	24.4	251	21.2	321	25.4	680	23.6	7.0

* Undoubtedly the most complete, and at the same time trustworthy, work ever done on the subject in any country at the time it was published.

AVERAGE INCREASES IN YIELD DUE TO TREATMENT, COMPARED WITH UNTREATED CROP.

Treatment	Spring Wheat		Barley		Oats		Spring Cereals as a Whole		
	No. of Expts.	Incr. in grain	No. of Expts.	Incr. in grain	No. of Expts.	Incr. in grain	No. of Expts.	Incr. in Crop	
								Gain	Straw
		%		%		%		%	%
Sprayed with solution of sulphuric acid	94	20.5	259	25.8	307	29.1	676	26.5	7.8
Sprayed with solution of nitric acid	25	19.5	47	21.1	49	26.8	122	23.3	6.1
Dusted with calcium cyanamide	85	18.5	248	24.0	283	25.0	630	23.9	12.2
Weeded*	54	19.7	100	23.5	100	26.6	258	24.2	6.0

In a further table, Korsmo shows both the average increases in grain and straw, and the percentage of weeds destroyed, by various treatments as compared with untreated areas. The following figures are abstracted :—

SPRING CEREALS.

AVERAGE INCREASE IN YIELD AND WEEDS DESTROYED, BY VARIOUS TREATMENTS, COMPARED WITH UNTREATED CROP.

Treatment	No. of Expts.	Increase due to Treatment		Weeds destroyed by Treatment
		Grain	Straw	
		%	%	%
Harrowed before germination of the cereals	194	12.9	3.3	46.3
Harrowed before and after germination of the cereals	116	15.7	5.3	63.9
Sprayed with solution of iron sulphate	269	22.8	5.1	82.5
Sprayed with solution of sulphuric acid	265	23.1	6.9	81.8
Sprayed with solution of nitric acid	58	23.1	9.1	73.0
Dusted with calcium cyanamide	253	24.4	13.8	78.8
Weeded*	132	24.4	6.0	88.8

*Apparently keeping the crop clean by hand-weeding, recognized as not economically possible, but done for comparison.

The percentage increases in yield of grain, shown in these tables, are of the greatest interest and importance, and clearly indicate the loss that must be taking place where weeds have complete freedom to run riot.

Perhaps enough has been said to indicate the losses that may be due to weeds—sufficient to induce us to take to heart Shakespeare's words :—

"I will go root away
The noisome weeds, that without profit suck
The soil's fertility from wholesome flowers."

—*Richard II*, Act III, Scene iv.

II.—Principles of Chemical Weed Control

Weed destruction by chemical methods is beset by various difficulties, for results may vary with temperature, rainfall, wind, local conditions of soil and situation—even perhaps the amount of dew on the leaf. Further, cost of treatment of crops is highly important: if an onion crop can be successfully treated at a cost of, say, £3 per acre, and an extra ton per acre is harvested, this must be of real advantage to the grower's bank account.

Chemicals are utilized for the destruction of plants for two specific purposes. (*a*) One object is to eliminate *all* vegetation from the areas concerned and prevent recolonization for as long as possible. (*b*) The other aim is to eradicate or control undesirable weeds, leaving the crops or grass unscathed, or so little damaged that recovery is rapid and the ultimate harvest is increased by the removal of the competition of the weeds.

(*a*) Complete removal of vegetation is desirable on such areas as paths, tennis courts, railway tracks and parts of aerodromes. This can be effected by treatment with high concentrations of toxic chemicals, sufficient not only to kill the existing plants, but to bring about a permanent or temporary sterilization of the soil by making it unsuitable to support plant life.

Compounds of arsenic are outstandingly efficient for this purpose, but in view of the danger to human beings and animals arising from their use, search is constantly being made for substitutes. Good results have been obtained with chlorates, boron compounds, salt, and oil residues, though the period of soil sterilization is often less than when arsenic is used.

(*b*) On cropped land a selective poison is required, and a wider range of chemicals, including fertilizers, is available, though weak concentrations of the above-mentioned soil sterilizers can often be used for this purpose. The principle of

selectivity depends very largely upon differences in the morphological development of weeds and crops, and on the varying resistance of different species to any chemical.

The fundamental point that determines the susceptibility of a plant is its power to retain the poison spray on its surface for a sufficient time to ensure penetration and killing of the tissues. Broad-leaved weeds, such as Charlock, hold the spray and are easily killed, whereas narrow-leaved upright plants like cereals afford little hold, so that the spray runs off without doing much damage. Protection is also afforded by a waxy surface, a dense hairy covering or a thick cuticle, any one of these protecting the tender tissues of the leaves.

Grasses and cereals are further guarded by the fact that the growing points are enclosed in sheaths, so that even if the unfolded leaves are damaged by spraying they are soon replaced as growth continues. Most broad-leaved weeds have the growing points exposed at the tips of the stem, and these are easily killed, preventing further development. In some instances, however, basal buds will survive, as often happens in Wild Radish, necessitating more drastic treatment if eradication is to be effected.

The retention of the spray fluid by broad-leaved plants, and on the exposed growing points so often present on such plants, occurs as much in crops as in weeds, and renders the spraying of broad-leaved crops a matter of great difficulty. Where protection is afforded by a covering of hairs or a waxy surface, spraying may be possible, but many crops will not withstand the treatment. Search is still being made for materials so selective in their action that it may yet be possible to use them to destroy weeds in broad-leaved crops without causing damage to the crops themselves.

Weeds that are able to resist the toxic action of sprays owing to these morphological peculiarities may often be controlled if a " wetter " or " spreader " is added to the spray enabling it to stick to the surface closely. Knotweed (Fig. 10 & Pl. XIV (a)) (*Polygonum aviculare*) resists ammonium sulphate spray (1 lb. to 1 gallon of water), owing to the waxy coating on the cotyledons and young leaves, but with the addition of ½ lb. soft soap as a wetter almost all the seedlings can be killed.*

* *Engledow, F. L., and Woodman, R. M.*, (1935). " The Use of a Wetter in Weed Spraying." *Jour. Min. Agric.*, XLII, p. 663–6.

Various other substances can be used as spreaders, and are purchasable under various trade names. Some of these, including dreft, are not affected by hard water, oxidising agents or moderate concentrations of mineral acids or bases, which introduce conditions that may render fatty-acid soaps ineffective as wetting agents in certain herbicides.

Annual weeds, which are entirely dependent upon seed production for reproducing themselves, can be controlled by the action of herbicides as contact sprays on the leaves, as leaf destruction implies starvation and death of the plant owing to the lack of reserve food materials in the underground parts.

Deep-rooted perennial weeds suffer only temporary damage from spraying, unless the material used is one that can penetrate and pass from the foliage down through the conducting tissues of the plant to the roots and underground stems. Such materials, known as translocated sprays, have proved very efficient under suitable circumstances for the control of Bindweed and Thistles. The most effective translocated spray is the acid arsenical, but chlorates, sulphuric acid, ammonium thiocyanate and, to some extent, oil, act in a similar way.

The range of chemical substances that can be used under one set of conditions or another for weed destruction is very wide, although a few well-recognised materials certainly overshadow the rest in importance and common use. Much research is being done on the subject in many countries, and fresh materials are constantly being brought forward. Sulphuric acid, copper sulphate, arsenic compounds and oils have been used for many years, whereas chlorates, Sinox and borax have only come to the front at various times during the last sixteen or seventeen years.

Very often the choice of spraying materials is influenced by questions of prime cost, transport, local production and cost of application, with due consideration of the results desired. With selective sprays the usual aim is control rather than eradication, the idea being to reduce the prevalence of the weeds sufficiently to shift the balance of competition so far that the value of the resulting crop exceeds the cost of the spraying—often considerably.

Time and weather conditions play an important part in determining the efficiency of spraying. It is usually best to

spray when crop and weed are both small, thus removing competition at an early stage. On the other hand, much can be done, if need be, to prevent the ripening and distribution of fresh seed by spraying when such weeds as Charlock are in the early, or bud, stages of flowering. Some sprays, such as sulphuric acid, act so quickly that rain falling within a few hours does not affect the results, whereas with slower-acting sprays such rain might wash off the poison before it had time to penetrate effectively.

Where fertilizers are used for weed control, either as sprays or dusts, it is possible to combine weed control with a profitable stimulation of the crop.

Experimental work makes it clear that no hard and fast rule can be laid down for chemical weed control, the position being admirably summed up by Robbins, Crafts and Raynor,* whose book on "Weed Control" is probably the most comprehensive of its kind yet published. "There can be no universal panacea for killing weeds. In any given situation, control methods must be adapted to the species and to the environmental conditions involved. In any practice that is to give success, the characteristics of the weed and their relation to the environment largely determine the reagent and method of application. General recommendations must be interpreted in the light of the specific situation, amended to meet the requirements imposed, and tempered with judgment based on local experience."

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* *Robbins, W. W., Crafts, A. S., and Raynor, R. N.* (1942). "Weed Control." p. 101 (McGraw Hill Book Co., Inc.).

See also "The Control of Weeds." *Herbage Publication Series,* Bull. 27, pp. 38-67, 1940.

Cook, W. H. and Halferdahl, A. (1937). "Chemical Weed Killers." A Review. Nat. Res. Council, Canada. Bull. 18, pp. 5-111.

III.—Effects of Fertilizers in Reducing Weeds

It is perhaps a trite saying that British farmers do not use sufficient fertilizers, but it is clearly certain that on the average the charge would hold true. In the *Journal of the Ministry of Agriculture** (1933-34) Messrs. Hunter Smith, Hudson and Gardner (Herts Institute of Agriculture) laid great emphasis on the very unimportant part played by artificials on the average farm—suggesting that, on economic grounds, farmers ought to supplement farmyard manure with "much larger quantities of artificial fertilizers" than they generally use. It may reasonably be asserted that, on the average farm, a judicious increase in the use of fertilizers would more than pay for itself by higher yields of better crops, at lower cost per unit. Yet of 300 farms in one county at that time over 25 per cent. used no fertilizers whatever !

The best farmers, horticulturists and market gardeners, however, are not only well informed as to the value of fertilizers in economic crop production, but are aware that the encouragement given to the crop enables it to withstand weed invasion, and frequently even to outgrow and suppress the bulk of the weeds. Many crops receive such a fillip from the fertilizers applied before sowing the seed, or as a top-dressing subsequently—as with nitrogen for cereals or sugar beet—that their strong growth largely carries them beyond weed competition. Not only so : some fertilizers not merely have the indirect action on weeds that has been mentioned, but they have a direct action in destroying them forthwith. Calcium cyanamide, sulphate of ammonia and finely-powdered kainit all possess both qualities when suitably employed. All fertilizers, however, have the indirect action in virtue of the plant stimulus for which they are employed. Further, the facts apply both to

* *Hunter Smith, J., Hudson, C. E., and Gardner, H. W.* (1933-34). Notes on Manuring. *Jour. Min. Agric.*, XL, pp. 771-777.

FIG. 1

FIG. 2

FIG. 1.—Yellow Rattle (*Rhinanthus crista-galli* L.) x about 2/3

FIG. 2.—Cut-leaved Crane's-bill (*Geranium dissectum* L.) x $\frac{1}{2}$, and flower natural size.

arable and grass land: and lime, phosphates, nitrogenous dressings and potash salts are all valuable in this way, according to climatic and soil requirements and the particular needs of the crops grown. Indeed, all fertilizers when judiciously used will tend to increase the crop, which is thus enabled to grow beyond the likelihood of severe damage from weeds.

It has often been held that mineral fertilizers tend to reduce weeds to a minimum and that nitrogenous manures encourage them. The point as to minerals appears to be generally true, but as regards nitrogenous fertilizers it deserves to be pointed out that whereas they do stimulate plant metabolism this perhaps applies to the crop even more than to the weeds growing among it, so that, as already observed, the crop can "grow away" from the weeds. The cleanest farms are usually those on which the soil is in the most fertile condition and is most thoroughly tilled. To be fertile it needs to be in the best physical condition, with a deep tilth, and to be well supplied with lime and plant food generally. Without adequate lime the physical conditions will be unsatisfactory, some crops cannot prosper, and useful soil organisms will not be maintained. Without adequate plant food from farmyard manure and/or chemical fertilizers the crops will not be so prolific in stem, leaf, grain or root, after their kind, as they ought to be.

Compared with a hundred years ago, or even with the time when Sir William Crookes (in 1898) expressed his fears about a famine in corn owing to dearth of nitrogenous fertilizers, we are now abundantly supplied with a great variety of chemical fertilizers, the products of modern scientific research. Among them may be mentioned sulphate of ammonia, nitrate of soda, nitrate of ammonia (as in nitro-chalk), urea, calcium cyanamide, nitrate of lime, muriate of ammonia, ammonium phosphate, bone flour, superphosphate, potassic superphosphate, basic slag, ground mineral phosphates, sulfurophosphate, basic superphosphate, potassic mineral phosphate, sulphate of potash, nitrate of potash, kainit, muriate of potash, potash salts, and combinations of certain of these to form some half-a-dozen high-grade compound fertilizers containing varying ratios of nitrogen : phosphoric acid : potash.

In these days of trials, experiments and research, most farmers have seen crops grown with varying quantities of fertilizers and with none at all, and must have noticed frequently the luxuriant

growth and cover due to good treatment. They need only be reminded also of the depressing effect on weeds of a heavy growth of wild white clover on many heavy-land pastures treated with phosphates; of the valuable effect of potash on many light-land soils; of the great benefit of top-dressings of nitrate of soda or sulphate of ammonia or cyanamide to corn crops; of the valuable stimulus of a top-dressing of nitrate of soda for hay, particularly in the presence of adequate phosphates and potash; and of the great changes brought about in many permanent pastures by repeated applications of small quantities of sulphate of ammonia, associated with close grazing. All artificial fertilizers should be distributed as evenly as possible: in this connection may be mentioned distributor trials conducted by Imperial Chemical Industries.*

The influence of different fertilizers on various species of weeds is by no means well known, but it is recognised that complete manuring is the best all-round treatment for the crop, which, growing at its best, is enabled to hold its own. For example, if grass is mown year after year and not manured it will steadily deteriorate in quality, and Yellow Rattle, Ragwort, Knapweed and other undesirable species may tend to become prominent. (Figs. 1 & 14. Pl. XIII.)

Here may perhaps be quoted what has been said elsewhere†:—

'It is essential that manurial treatment should not be one-sided; while the present-day intensive treatment of grass land with nitrogen, for purposes of close grazing, is quite sound, care must be taken to ensure that phosphates and potash are present in sufficient quantity, this depending very much upon the soil type. If ample minerals are present, nitrogen may be used frequently in small quantities, and if the repeated flush of herbage is regularly grazed off, or mown, an improvement in the grass land, with a reduction in the weed flora, may be anticipated. Nitrogen alone is very unsatisfactory; nitrate of soda appears to tend to an increase of weeds and coarse grasses in the greater bulk of hay, but to a reduction in clovers; sulphate of ammonia, on the other hand, encourages Sheep's Fescue, Bent and Sheep's Sorrel; phosphates and potash alone encourage clovers, but do not suppress Sorrel and Yarrow; lack of potash has led to an increase in Knapweed, Yarrow, Plantain and Buttercup; superphosphate applied alone continuously is possibly as exhausting as nitrogen alone; basic slag on 'slag land' notoriously effects a remarkable improvement of the herbage, encouraging clovers and incidentally reducing the percentage of weeds and grasses present.

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* *Keeble, F.* (1930). New Methods of Testing Fertilizer Distributors. *Jour. Min. Agric.*, XXXVII, pp. 439-451.

† *Long, H. C.* (1932). Weeds of Grass Land. *Min. Agric.*, Bull. No. 41.

FIG. 3.—Dandelion (*Taraxacum officinale*, Wigg.) x about $\frac{1}{2}$.

" It was observed by Armstrong* in 1907 :—

That the choicest grazing land is invariably associated with soil rich in available phosphates.

That on soils suitable for permanent pasture, inferiority of the herbage is generally due either to (1) a deficiency of available phosphates, or (2) to their bad mechanical condition.

That herbage of the best grazing land may be twice as rich in nitrogen and phosphate as that of a poor pasture, and that this large difference appears to be directly determined by the proportion of white clover present, and indirectly by the percentage of available phosphates in the soil.

"Investigations in 1927 in connexion with trials† on the improvement of grass land by close sectional grazing, nitrogenous manuring, etc., indicated that the only weed species that showed signs of increase under the new system was Yarrow. The inferior grass, Yorkshire Fog, showed very considerable active growth during the whole season. There seems to be some tendency for clover to be reduced by repeated doses of nitrogen and close grazing, but if this is not carried too far, and the autumn-spring herbage is increased, then the general effect is valuable."

This is not the place to deal fully with the effects of fertilizers, purely as such. As already indicated, where plots in the same field are respectively kept free from weeds and permitted to grow weeds there is a considerable loss of crop on the weedy plots. If the weeds can be largely suppressed by the encouragement of crop growth by the use of fertilizers, or if they can be directly destroyed by certain fertilizers or chemical substances without injury to the crop, this will be all to the good—provided the treatment is economically sound.

The value of fertilizers in crop production is illustrated in Pls. III, IV, V.

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* *Armstrong, S. F.* (1907). The Botanical and Chemical Composition of the Herbage of Pastures and Meadows. *Jour. Agric. Sci.*, II, pp. 283-304.

† *Rt. Hon. Lord Bledisloe, K.B.E.*,"The Intensive Treatment of Grass Land." 1928.

IV.—The Use of Lime

Lime is recognized by practical farmers and scientific opinion alike as almost a specific reducer of certain weeds that only flourish on acid soils or soils containing very little lime in the top few inches. Bracken, Spurrey (Fig. 4, Pl. VI), Corn Marigold, Sheep's Sorrel (Pl. I), Ox-eye Daisy, Cornflower, Gorse and Broom, are all most plentiful on soils poor in lime, and will be gradually reduced by applications of lime in some form. In using lime, however, it must not be expected that results will necessarily show in the first year: the effect of liming will be progressive, and, up to a point, dependent upon the size of the dressing. It must be remembered, also, that most farm crops are most successfully grown on soils containing an adequate supply of lime; some crops, indeed, such as barley, sugar beet, turnips, clovers, may fail entirely on acid soils (Pl. VI).

The benefits of liming need not be discussed here in detail: they will be found in such works as *Grass Land*, by Stapledon and Hanley; and three bulletins issued by the Ministry of Agriculture—No. 3, *The Improvement of Grass Land*; No. 35, *The Use of Lime in Agriculture*, and No. 41, *Weeds of Grass Land*.

Quite apart from the effect of lime in improving the physical condition of the soil, facilitating drainage, encouraging useful soil organisms, making plant food available for crops, and itself providing plant food, lime is also beneficial in making the conditions unsuitable for certain weeds. With unbalanced manuring, as with potash and nitrogen without phosphate, liming may greatly encourage such weeds as Dandelion, (Fig. 3), as has happened on the Rothamsted grass plots. On the other hand, with complete mineral manures liming has led to a great increase in the proportion of leguminous plants, coupled with a reduced proportion of weeds.

In addition to the species already mentioned, some other weeds are adversely affected by lime—for example, Sedges, Rushes and Horsetails, though the liming may need to be associated with draining. At Cockle Park, the percentage of

Bent and Yorkshire Fog (Pl. II.) was much reduced by liming, though Ribwort was increased. Lime may be expected to have its fullest effect in reducing weeds when applied in conjunction with such fertilizers as may be required for the particular soil and climatic conditions, and in association with grazing by different classes of stock.

It is generally agreed that a very large proportion of our cultivated land still contains insufficient lime and would be much improved by applications varying from 10 cwt. to 2 tons per acre, to be repeated at suitable intervals—perhaps 10 to 20 cwt. every fourth year.

Fig. 4.—Seedlings of Spurrey (*Spergula arvensis* L.), nat. size.

Fig. 5.—Seedlings of Groundsel (*Senecio vulgaris* L.), nat. size.

V.—Sulphate of Ammonia and Nitrate of Soda

The outstanding position held by ammonium sulphate and nitrate of soda as nitrogenous fertilizers lends an added importance to the fact that they are able to act as effective weed killers when applied as sprays. For certain weeds they are particularly effective, and their relatively heavy cost is offset by the increased crop due to the extra nitrogen supplied as well as to the reduced weed competition. Ammonium sulphate is the more generally reliable as a weed killer, but nitrate of soda has also given good results.

Sulphate of Ammonia.—The uses of sulphate of ammonia as a fertilizer are, of course, well known to most farmers. In quite recent years we have seen how valuable it is in encouraging the growth of grasses on permanent pastures, when it is applied evenly in small doses at intervals of a few weeks. Persistent treatment, combined with judicious grazing, will result in a steady reduction of the weed flora. On grass land the individual dose is usually in the neighbourhood of 1 cwt. per acre ; for arable crops larger quantities are employed. (Pl. VII).

Applied in large quantities sulphate of ammonia may check the growth of vegetation for a time or kill it altogether. In considerable quantities at the wrong moment it may have an adverse action on the germination of seeds. In reasonable amount and in special circumstances, however, it has been used from time to time for direct application to crops in order to destroy weeds growing among them. Like other nitrogenous fertilizers, sulphate of ammonia should be used in the presence of adequate supplies of phosphates and potash, as well as of lime.*

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* *Singh, B. N., and Das, K.* (1938). Effectiveness of Spraying with Fertilizers for Control of Weeds on Arable Land. *Jour. Amer. Soc. Agron.*, XXX, pp. 465-74.

Sulphate of ammonia may be used either alone or in conjunction with a non-fertilizing spray-material such as copper sulphate or sulphuric acid, a smaller quantity then being needed.

FIG. 6.—Corn Buttercup (*Ranunculus arvensis* L.) x about ½.

Sulphate of ammonia has a corrosive effect on copper, so that special care is needed to clean all parts of the spraying machine very thoroughly, and to wash with clean water even during temporary stoppages of work.

In various parts of England sulphate of ammonia has proved effective in eradicating Charlock, Wild Mustard, Ivy-leaved Speedwell, Large Field Speedwell, Spurrey and Sheep's Sorrel,*

* *Porter, J.* (1922) "The Spraying of Cornfield Weeds with Sulphate of Ammonia." *Jour. Min. Agric.*, XXVIII, pp. 1109-16.

(*Photos copyright* *H. C. Long*)

Sheep's Sorrel (*Rumex acetosella L.*): *a* (left), flowering stage; *b* (abcve) pre-flowering stage.

To face page 18

PLATE II

Photo lent by) *(S. F. Armstrong & Cambridge Univ. Press*

Yorkshire Fog (*Holcus lanatus* L.)

PLATE III.

Photo lent by) *(Imperial Chemical Industries*

Wheat: *Further Plot* .complete Fertilizer *Nearer Plot*, without Fertilizer.

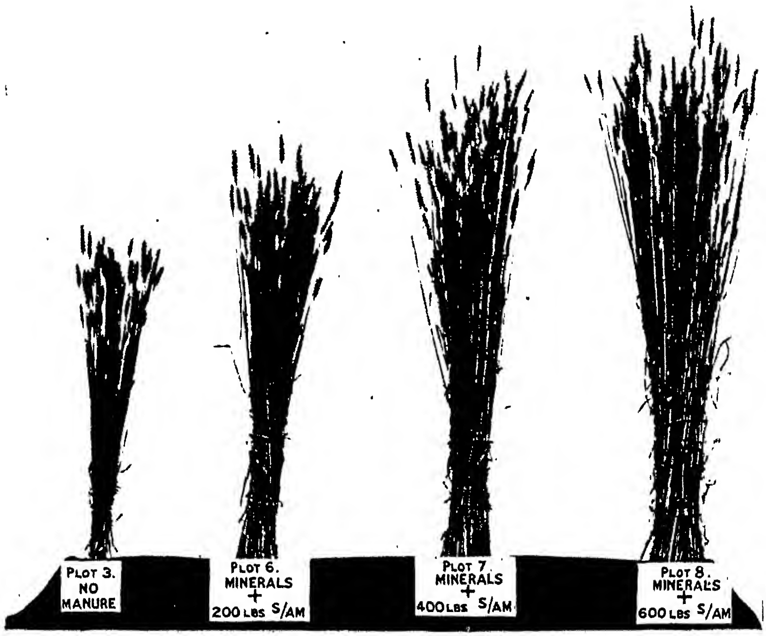

Photo lent by) (*Rothamsted Experimental Station*

WHEAT GROWN ON BROADBALK FIELD, ROTHAMSTED EXPERIMENTAL STATION.

Continuous wheat 1843-1925 (except 1915 fallow), then cycle of bare fallow followed by successive wheat crops.

Produce of 1943 : The Hundredth Season : 95th crop.

Section 4 fallowed 1915, 1928, 1929, 1934, 1939.

FOURTH CROP AFTER FALLOW.

PLOT 2 : 14 tons Farmyard Manure per acre.

PLOT 3 : Without manure of any kind since 1839.

PLOT 5 : Sulphate of Potash 200 lb., Soda 100 lb., Magnesia 100 lb., and Superphosphate 3.5 cwt. per acre.

PLOT 6 : Minerals as Plot 5 and 200 lb. Sulphate of Ammonia = 43 lb. N. per acre.

PLOT 7 : Minerals as Plot 5, and 400 lb. Sulphate of Ammonia = 86 lb. N. per acre.

PLOT 8 : Minerals as Plot 5, and 600 lb. Sulphate of Ammonia = 129 lb. N. per acre.

PLOT 16 : Minerals as Plot 5, and 550 lb. Nitrate of Soda = 86 lb. N per acre.

PLATE V.

Photo lent by) *(Rothamsted Experimental Station*

2 3 5 6 7 8 16

Photo lent by) (*Sir John Russell*

(a)—Woburn Permanent Barley Plots: Limed Area growing crop; un-limed no crop, full of Spurrey.

Photo lent by) (*H. W. Gardner*

(b)—On the experimental fields under the control of A. W. Oldershaw, on light land, at Tunstall, E. Suffolk, July, 1933. Ground on right Chalked, on left Unchalked. Sugar beet almost completely failed on the acid soil. Potatoes (middle distance) flourished on both parts in the early part of the season. Later, drought affected the Unchalked Potatoes very severely and they were a much smaller crop than those on the Chalked land.

Photo lent by) *(Imper. Chem. Ind.*

(a)—A Bent Sward on a Sandy Soil infested with Moss and Mouse-ear Hawkweed.

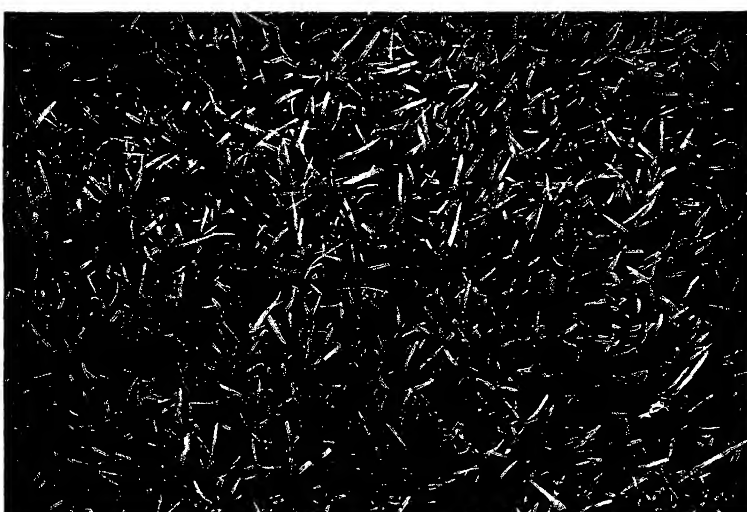

Photo lent by) *(Imper. Chem. Ind.*

(b)—As (a) after treatment with periodic applications of Sulphate of Ammonia at the heavy rate of 5lb. per 1,000 sq. ft. fortnightly from May-Sept., watered in.

Photo lent by) (*Messrs. Shaw Scott & Co.*

(a)—Charlock Destruction. *Left*: Top-dressed with 2 cwt. per acre Cyanamide. *Right*: Untreated.

Photo lent by) (*Messrs. Shaw Scott & Co.*

(b)—Charlock Destruction. *Left*: $1\frac{3}{4}$ cwt. per acre Cyanamide. *Right*: Untreated.

and in reducing other species, but Black Mustard, Black Bindweed and Sowthistle are little affected. At some stages Charlock needs 2 cwt. per acre for eradication, and for cereal crops this is only to be recommended in serious cases or where the soil is deficient in nitrogen, partly because of the risk of damaging the crop or of deterioration of the grain, especially malting barley, but also because the cost per acre is uneconomic. Further, the time required to dissolve the large

FIG. 7.—Charlock Seedlings (*Sinapis arvensis* L.), nat. size.

bulk of sulphate of ammonia in a comparatively small quantity of water slows up the work considerably and renders the operation tedious. In 1943 Hertfordshire farmers destroyed Charlock by using a mixture of 14 to 20 lb. finely-powdered crystalline copper sulphate mixed with 1 cwt. fine and dry sulphate of ammonia per acre, distributed in the early morning when the dew was on the leaves.*

Young plants of thistles are reported as being killed by 1 cwt. of sulphate of ammonia in about 80 gal. per acre,† though

* *Min. Agric.* Weekly News Service No. 192, July 10, 1943.

† *Rabaté, E.* (1927) "La Destruction des Mauvaises Herbes." *L'Agriculture Pratique*, Lib. l'Acad. d'Agric., pp. 35-6.

old plants are resistant to even larger dressings. The addition of a proportion of sulphuric acid killed almost all natural weeds, including Wild Radish, and the fertilizing effect of the nitrogen on the oat crop was very marked.

The chief value of sulphate of ammonia lies in dealing with special weeds that are locally very troublesome and do not respond so readily to the usual methods of treatment. Corn Buttercup (or Starveacre), Hoary Pepperwort (Chalk Weed or Thanet Weed) and Spotted Medick afford notable instances of this.

Corn Buttercup or Corn Crowfoot,—When young plants in winter wheat were sprayed with 2 cwt. of sulphate of ammonia in 50 gal. of water the leaves withered and the weeds appeared to be killed, but after a few weeks a certain percentage recovered sufficiently to flower and produce seeds.* The next year spraying was delayed until the weed was just coming into flower, with the result that the plants were killed outright and seeding entirely prevented.† An ordinary horse-drawn Charlock spraying machine was used, with a few special precautions. Calm and dry weather conditions were essential for success. Other trials with 1½ cwt. sulphate in 60 gal. per acre proved equally successful,‡ at least 75 per cent. of the plants being killed and the rest so damaged as to prevent them from setting seed. (Fig. 6).

Hoary Pepperwort, Thanet Weed or Chalk Weed.—During recent years this weed has become a serious menace in various parts of the country, especially in Kent and Essex. A definite experimental campaign was carried out from 1918-22 under the guidance of the agricultural organizers, with most encouraging results, as it was proved that Thanet Weed can be kept under if dealt with resolutely.§ Here again, spraying before the weed is fully grown is not effective, for though the old leaves are killed fresh green growth appears at the top of each plant.

* *See ref. on p.* 18.

† *Porter, J.* (1922) " The Spraying of Cornfield Weeds, with special reference to *Ranunculus arvensis* (Starveacre) in Winter Cereals." Agric. Educ. Assoc. Meeting, pp. 21-22.

‡ *Gaut, R. C.* (1921) " Spraying with Sulphate of Copper and Sulphate of Ammonia for the Destruction of Weeds growing among Corn." Worcester Agric. Committee, pp. 1-7.

§ *Garrad, G. H.* (1923) " Hoary Pepperwort or Thanet Weed." *Jour. Min. Agric.*, XXX, pp. 158-162.

The best results were obtained where the weed stood up well above the crop in which it was growing, as otherwise the corn offered too much protection. Oats and wheat were successfully sprayed with $1\frac{1}{2}$ and 2 cwt. sulphate of ammonia in 60 gal. of

FIG. 8.—Charlock, or Wild Mustard (*Sinapis arvensis* L.) x about $\frac{1}{2}$.

water early in May, and even as late as June 6 a heavier dressing of 3 cwt. of sulphate in 90 gal. of water was effective in killing the weed without damaging the wheat to any serious extent. In the latter trial a few weeds escaped injury owing to protection by the crop. An encouraging feature was a report from an

Essex farmer,* who used the method independently, and after spraying with 2 cwt. sulphate of ammonia per acre the weed did not recur the following year, though previously it had appeared regularly each May.

Excellent results have also been obtained over thousands of acres by the use of a mixed spray, with 56-64 lb. ammonium sulphate and 14-16 lb. copper sulphate in 70 to 80 gal. of water per acre.† Young lucerne, as well as cereals, suffers nothing more than a temporary scorching, but winter barley is seriously damaged if circumstances demand a second spraying. Where Thanet Weed is a pest, therefore, there is much to be said for spraying with sulphate of ammonia, either with or without the admixture of copper sulphate, especially on soils where nitrogenous fertilizers are known to be beneficial. During recent years, however, the method seems to have been little used, possibly because the control is not permanent and the weeds reappear later, either from seeds buried in the soil, or from surviving portions of underground parts.

Spotted Medick.—Though this may occur among cereal crops, it is only troublesome in pastures, where it spreads rapidly into dense patches that kill out the underlying vegetation and after fruiting die out themselves, leaving the ground bare of grass and free for the incursion of weeds.‡ Wet sprays are useless, but dusting the patches with dry sulphate of ammonia, from 5 to 12 oz. per 8 square yards (equivalent to 2 cwt. and upwards per acre) is effective under suitable weather conditions. The work should be done in early spring, before flowering and while the leaves are young, in dry sunny weather when the leaves are moist with dew. Action is slower in dull periods, and in wet weather results are not satisfactory. After the Medick is killed it is sometimes advisable to sow a little grass seed if the patches are quite bare of vegetation. The application of basic slag too soon after treatment should be avoided, as it tends to stimulate the growth of the dormant Medick seed, so undoing the benefit of the "dry spraying" with ammonium sulphate.

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* *Wilkes, J. F.* (1924.) "Hoary Pepperwort." *Essex Far. Jour.*, III, No. 4.

† *Robson, R.* (1919-20.) "Control of the Weeds Whitlow Pepperwort and Black Mustard." *Jour. Min. Agric.*, XXVI, pp. 53-63.

‡ *Fenton, E. W.* (1922.) "Spotted Medick." *Jour. Min. Agric.*, XXIX, pp. 643-8.

A warning is needed as to the use of ammonium sulphate, as it kills clover seedlings and severely injures peas, beans, vetches and potatoes. Its use is, therefore, precluded where corn is seeded with clover. On the other hand, where nitrogen is required it might possibly be used more commonly than it is for the dual purpose of fertilizer and direct destroyer of Charlock and other annual weeds in their young stages. It might also be used in the dry state in finely-powdered form.

Nitrate of Soda.—In experimental work with ammonium sulphate, nitrate of soda has usually been tested as well, but has proved to be less generally satisfactory, though sometimes effective. The growth of Spotted Medick, for instance, is stimulated by nitrate of soda, even with heavy dressings at the rate of 3½ cwt. per acre. Charlock also seems very resistant to its action, as in Cambridge experiments 1½ cwt. in 40 or 80 gal. per acre had no appreciable effect on the Charlock, which flowered after spraying.* In Scotland, also, both Charlock and Wild Radish, though somewhat checked, came into flower with even stronger sprays up to 3 cwt. nitrate per acre.† The crops, however, were benefited by the fertilizing action of the nitrate, though not to the same extent as where weed competition was removed by spraying with copper sulphate. Continental experiments indicate that Goosegrass and Speedwells can be killed by fairly heavy sprays of nitrate, while Dandelion, Bindweed and Spurrey are severely injured, the oat crop remaining unharmed except for a temporary scorching of the leaves. Heavy dressings of nitrate, apparently spread in the dry state at the beginning of May, are also credited with killing Poppies, Chickweed, Sorrel, Wild Vetches, and the aerial parts of Thistles, but the quantities suggested are unduly high and would be uneconomic, even if not unsafe, to apply under ordinary farming conditions. Similar treatment with 8 cwt. per acre will destroy Dodder and at the same time strengthen the lucerne or other leguminous host, thus enabling the latter to resist the drain of the parasite to a greater degree. As regards Corn

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* ——(1901-2.) "Destruction of Charlock by Spraying." Camb. Univ. Dept. Agric., Fourth Ann. Rept., pp. 15-16.

† *Wright, R.P.* (1904.) "Report on Experiments in 1901-3 on the Destruction of Charlock and Runch in the Oat Crop by Spraying." W. of Scot. Agric. Coll., Bull. 22, pp. 43-61.

Buttercup, nitrate of soda at the rate of 1 cwt. in 60 gal. per acre is not a very satisfactory spray, though it stimulates the covering cereal crop.*

Nitrate alone does not appear to have been tested against Thanet Weed, but 56 lb. nitrate and 14 lb. copper sulphate in 70 gal. per acre will reduce it, in some instances being as effective as a similar mixture with ammonia sulphate, but in others considerably less so.† Mixed sprays of copper sulphate (8-12 lb.) and nitrate of soda (18-30 lb.) in 40-60 gal. of water per acre also killed Black Mustard in oats when applied at the beginning of June.‡

The somewhat irregular and uncertain behaviour of nitrate of soda when used as a weed spray does not recommend it for general use. In some circumstances, however, where it is not desired to use ammonium sulphate, but where the need for a nitrogen fertilizer exists, nitrate of soda may serve a useful purpose in this respect, particularly if its weed-killing powers are strengthened by the addition of a small proportion of copper sulphate or similar toxic agent. Nitrate of soda is not usually recommended for direct weed destruction, but rather as a stimulant to enable the crop to grow strongly and suppress weeds.

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* See † p. 20. † See § p. 20. ‡ See † p. 22.

VI.—Calcium Cyanamide

During the years before the war there was a steady increase in the evidence that, quite apart from its high value as a nitrogenous fertilizer, calcium cyanamide has a very special use as a weed killer. Not only does cyanamide contain 20 to 22 per cent. of nitrogen, but each ton contains the equivalent of 12 cwt. of quicklime. The material is very finely divided and readily available. Certain compounds included in it, however, render it, when first distributed, injurious to plant life, but these injurious constituents are decomposed in the soil in the course of a few days. For this reason it is common practice to apply cyanamide to the soil a week or so before sowing seed or transplanting, and it is believed that the best results are sometimes—as for sugar beet—obtained by applying it immediately before the final ploughing, or even earlier. As a weed destroyer, however, cyanamide may be broadcast with safety on cereals, either in autumn or spring; the cereal may on occasion be somewhat browned at the leaf-tips, but will quickly recover, whereas many annual weeds, especially those having broad and rough leaves, will be destroyed. The reason for this selective action depends partly upon the fact that cereals are narrow-leaved, smooth and upright, while most weeds have broad and more or less rough leaves, with somewhat horizontal growth—so that they " hold " much more of the finely-powdered cyanamide than the cereals.

It may, therefore, be said that cyanamide is of value in several ways :—

(*a*) As a highly nitrogenous fertilizer, for general use as such, to be applied to arable land before the seeds are sown, or to grass land.

(*b*) As a carrier of a high percentage of lime, of special use on acid soils, and with crops—barley, turnips, sugar beet—that require lime and will not do well without it.

(*c*) As a destroyer of weed seedlings when distributed on arable land as under paragraph (*a*); when applied as a top-dressing to cereals (and perhaps some other crops) in autumn or spring; or when used on grass land.

In relation to (*a*) and (*b*), it will be understood that, in stimulating and feeding the crop, cyanamide enables the crop to grow away from or suppress weed growth. It should, however, be borne in mind that, as a fertilizer, cyanamide should be used —like other nitrogenous fertilizers—in association with an adequate supply of phosphates and potash. In this connexion it may be said that on the Continent cyanamide is sometimes mixed with sylvinite or kainit for use in weed destruction, the potash salt being supposed to aid in killing the weed and thereafter providing food for the crop. More recent work,* however, does not provide conclusive evidence of this accelerating action of potash.

A general review of the available data regarding trials with cyanamide clearly shows that there is much trustworthy evidence to prove its value both as a fertilizer and a weed destroyer—the latter particularly in cereal crops. On the Continent it is widely used, and in greatly increasing quantities. For example, it is stated that the quantity used for weed destruction in Germany rose from 20,000 tons in 1926 to 52,000 tons in 1930. Reference may be made briefly to a few of the instances in which trials have been made.

In Bavaria, trials with cyanamide on oats to kill Wild Radish gave results that speak for themselves. The best results were obtained when the material was applied when the crop was wet with dew and the weed had two to four leaves. In five trials the average number of Wild Radish plants per square yard was 368 where phosphates and potash were used, but only 17 when cyanamide was applied in addition. The quantity of cyanamide used was approximately 1½ cwt. per acre.

Another German report (Nov., 1932) showed that cyanamide was valuable for winter corn, for use in November and December, when weed plants were greatly reduced as compared with application in October or March. Compared with plots getting no cyanamide, application in November and December reduced the weeds to 6½ per cent. and 4 per cent., respectively.

In yet another instance experiments gave a very considerable reduction of Wild Radish and an increase in grain yield—in four trials an average increase of 75 per cent.

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* *Beling, R. W., Utsch, W., and Pfingsten, E.* Über die Ursachen der Unkrautbekämpfung durch Kalkstickstoff. *Bodenk. Pfl. Ernähr.*, 19, pp. 201–18.

Korsmo's trials, as indicated in the table on page 3, showed that in 630 experiments with spring cereals cyanamide gave an average increase of 23.9 per cent. of grain and 12.2 per cent. of straw.

Dutch, Belgian and French trials on arable land also indicate very considerable success with cyanamide against various weeds, especially Charlock, Wild Radish, Speedwell, Pimpernel, Corn Cockle, Goosefoot, Poppy, Corn Marigold, Chickweed, Knotweed, etc., while Horsetail, Coltsfoot and Thistles may also receive a severe set-back. On grass land, Geranium (Fig. 12),

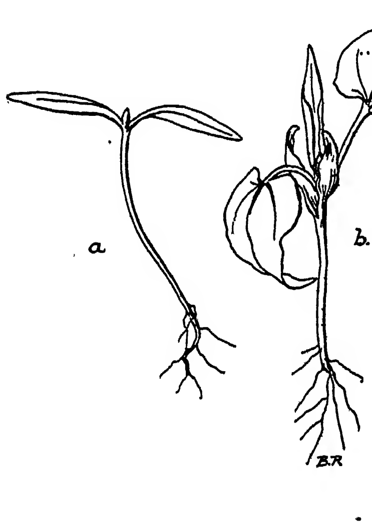

FIG. 9.—Seedlings of Black Bindweed (*Polygonum convolvulus* L.), nat. size.

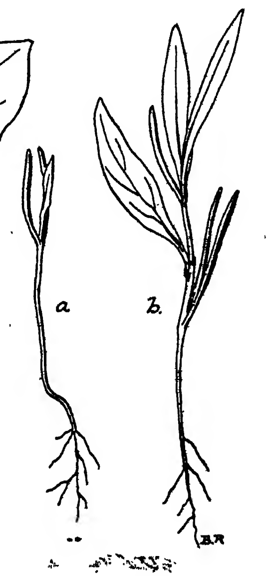

FIG. 10.—Seedlings of Knotweed (*Polygonum aviculare* L.), nat. size.

Plantains, Daisies, Buttercups, Lady's Smock, Yarrow, Sedges and some other weeds have been much reduced, especially when the cyanamide has been used with phosphates and potash, while Yellow Rattle is stated to be severely affected. For grass land, late winter or early spring application is said to be best; in Great Britain, however, autumn or early winter, or early spring dressings are most satisfactory—it is not desirable to distribute cyanamide when the ground is frozen.

Ten years ago the Dutch used about 8,000 tons of cyanamide for weed destruction annually, and almost the whole of it for destroying Cornflower in winter corn.

In France and some other countries on the Continent cyanamide is used mixed with sylvinite or kainit, sometimes with phosphates added, so that weed eradication goes hand in hand with complete chemical manuring. One mixture used in France for cereals was said to contain 4.5 per cent. of nitrogen and 13.5 per cent. of soluable potash, and was used at the rate of 4 to 5 cwt. per acre. Jaguenaud* found that he obtained the best results with a mixture of two parts of cyanamide, one part sylvinite and one part phosphate (kind not stated), applied in spring during white frost at the rate of 6½ to 8 cwt. per acre, a rather heavy dressing.

Before giving final recommendations, a word is advisable as to method of distribution. Some care is necessary, as the material is admittedly not pleasant to handle. The London representatives advice was as follows :—

> "The fertilizer should be distributed as evenly as possible, preferably on a calm day, by means of a suitable fertilizer distributor. When handling cyanamide it is advisable to oil the hands and arms freely before commencing work, and to remove the dust with an oily rag immediately after work and before washing. Cyanamide must not be allowed to come into contact with cuts or wounds."

It is not easy to fix a definite time for the application of cyanamide, since a good deal will depend upon the season and the state of the crop. It is certainly possible, however, to use cyanamide for direct application to cereals either in autumn or spring, to distribute it at any time of the year a week or two before sowing seeds or transplanting, or to apply it on grass land in early winter or early spring—keeping stock off for a few days until rains or heavy dews have washed it off the grass. There are circumstances in which it is not desirable to use it, as for cereals after sheep, when added nitrogen is not required and is likely to cause the cereals to lodge ; after sheep, sulphuric acid spraying is to be recommended instead.

It can be recommended that cyanamide may be used at the rate of 1 to 1½ cwt. per acre, sometimes rather more, for corn crops, turnips, grass land and bush fruits : 2 to 3 cwt. per acre

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* *Bul. de Renseignement du Service Agricole*, Nov., 1929.

for potatoes, sugar beet and fruit trees ; and as much as 2 to 4 cwt., or even up to 6 cwt. per acre for market garden crops. Usually it should be applied a week or so before sowing seed or putting out plants. The importance of early application must be emphasized. (Pl. VIII).

For destroying weeds in cereals a top dressing of 1 to 1½ cwt. per acre may be applied when the cereals are well established and the weeds are still small. This will, of course, depend upon weather conditions, the state of the crop, and the type of weeds. The best time is when the crop is moist ; many authorities advise when the dew is on the leaf during a dry spell. Some skilful farmers seem to be able to use cyanamide as a top-dressing for sugar beet in the young stages without injury to the beet, but this is attended with some risk, and is not recommended ; any farmer is strongly advised to try a very small area before venturing to dress a whole field. On grass land the best periods for dressing are autumn, early winter and early spring.

At the time the first edition of this book was being prepared, Mr. J. Laird (College Farm, Hertford) stated that he had top-dressed all kinds of crops with cyanamide in spring, and had had no ill effects. He wrote :—

> " What I like about it is that you can omit the nitrogen for your spring crops and put the cyanamide on as a top-dressing when the corn is about 3 in. high and the Charlock and other annual weeds are in the early stages. In that case it costs nothing for killing the Charlock, as you have the full value for your nitrogenous dressing. Then for mangolds and sugar-beet I like to harrow it in lightly about a week before sowing the seed, and I find it kills the annual weeds as they germinate and they are not there later on to stifle the young plants. I have never had a crop injured to speak about, and the quick action of the nitrogen after, more than compensates for the two or three days' hindrance. I have one of the worst fields for Charlock in this county, and the cyanamide has always turned it down."

Mr. W. Brown (Goodwood Home Farm, Chichester) stated that he had only used cyanamide for the destruction of one weed, White Charlock or Wild Radish, and under certain conditions had had 100 per cent. kill, but so far had not been able to determine the ideal conditions. The difficulty has been even distribution, but he thought a new machine he had should do the job well. For ordinary Charlock cyanamide is very effective where the distribution is even. Although he had not

really discovered the right quantity to use for best effect, he said :—

"I rather think that about 1 cwt. is about as much as one can use, as the fertilizing effect has a tendency to put the corn down, but I am convinced that with experience in distribution we have the means of destroying the Charlock.

Another correspondent, Mr. H. J. Gubbin (Peasmarsh, Sussex), gave an example of the use of cyanamide on Charlock. He had a particularly bad case of Charlock in oats. In March, 1932, he sowed an 8-acre field to spring oats, which came on very nicely and looked very well the first two or three weeks; but in a large part of the field Charlock also came on in most alarming thickness. He proceeded to say that :—

"By the second week in May I could see that about 3 acres of the field would produce very little oats but an abundant crop of Charlock unless something was done. I happened to have 3 bags (6 cwt.) of cyanamide by me, so I decided to broadcast this on the 3 acres. This I did, and for about a fortnight that part of the field was quite brown and everything appeared to have been killed, but eventually the corn came through, turned a dark green colour, and yielded approximately 6 qr. to the acre, with straw quite the normal length. The Charlock was not killed outright, but was so checked that very little of it was cut and bound with the corn."

"My experience has been that cyanamide only kills very young annual weeds, but will sufficiently check all weeds—including Docks and Thistles—to allow of a moderately clean corn crop."

"In the above case the application was about three weeks too late to give the best results. The best time is about three weeks after the corn is up and when no dew or rain* is on the corn."

"I have never had corn permanently damaged."

Mr. W. J. Lane (Farms Manager, Coventry and District Co-operative Society, Ltd.) dressed 20 acres of winter oats, which were smothered with Speedwell, with 1 cwt. of cyanamide per acre. The oats were 5—6in. high, and the Speedwell was in full flower. Mr. Lane observed that :—

"After applying the cyanamide the weeds and the oats gradually withered up, but after about three weeks the oats recovered and did remarkably well. When they were cut, the stubble was perfectly clear of weeds. I was so pleased with the result that I intend doing any fields on which Speedwell and other weeds grow.

* The London agents of cyanamide advise application when the plant is moist, and not when dry.

VII.—Sulphuric Acid

About 1896 Bonnet, a Frenchman, introduced the method of destroying Charlock by spraying infested cereal crops with a solution of copper sulphate, and over a considerable period this remained the chief means of killing this troublesome weed. Early in the present century, however, the French developed the idea of using other substances, and sulphuric acid soon began to replace copper sulphate, so that in France it became the recognized means of combating Charlock, Wild Radish and various other weeds, and about 500,000 acres were treated annually. The method is also widely used in other European countries and on the continent of North America. Yet, although up to that time it had been tried a number of times in this country, and was found effective against Bracken in Scotland,* it is only during the last ten years or so that it has found a definite place in British agriculture. There is little doubt that sulphuric acid is destined to play no small part in weed destruction in the future. It may be noted, as a matter of real interest to farmers, that the area sprayed with sulphuric acid has increased rapidly, having been estimated as only 200 to 300 acres in 1931, whereas by 1937 it had risen to 30,000 acres in England.

According to Rabaté† the use of sulphuric acid was popularized in France by agricultural societies and similar bodies. He gives an account of its use against weeds in cereals, flax, lucerne and grass. With 8 to 10 per cent. solutions of acid (65 deg. Baumé) he cites as "quickly scorched" Corn Buttercup, Charlock, Wild Radish, Knotweed and spp. of *Matricaria*, and says that with 12 to 14 per cent. solutions Poppies, Shepherd's Needle and Corn Cockle are killed. In flax a 10 per cent.

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* *Gordon, G. P.* (1916.) Bracken: Life History and Eradication. *Trans. Highland and Agric. Soc.*, XXVIII, pp. 92-106.

† *Rabaté, E.* (1926.) The Use of Sulphuric Acid Against Weeds and Certain Crop Parasites. *Int. Rev. Sci. and Prac. Agric.*, IV, N.S., pp. 535-45.

solution (105 gal. per acre) on May 15 completely withered Wild Radish, Sowthistle and Creeping Thistle in five days, and the flax remained uninjured. Lucerne given a 10 per cent. solution in January was scorched, but had recovered fully by March 20, but Sowthistles, Dead Nettles, Ribwort and Hawk's-beard had disappeared.*

The same authority,† writing in 1911, recommends a 5 per cent. solution against Wild Radish in winter wheat, in calm, fine and dry weather between February 1 and March 15, when the weed will largely have germinated. A 10 per cent. solution is more effective, and if the cereal is scorched it will recover in 8 or 10 days. For spring cereals he suggests preliminary trials with solutions varying between 3 and 7 per cent. A top-dressing of nitrate of soda may usefully follow later.

In a 1918 report of the German Agricultural Society, on the distribution and control of farm weeds in Germany, it is recalled that in 1913 Gelpke showed that a 3½ per cent. solution of sulphuric acid (66 deg. Baumé) at the rate of about 130 gal. per acre only slightly injured oats and wheat, but killed Charlock, Chickweed, Poppy, Shepherd's Purse, Stinking Mayweed, and—apparently the tops only—Field Bindweed, Creeping Thistle and Dandelion.

In the spring of 1925 (March 28) trials were made in Saône et Loire against various weeds with 10 per cent. solution of acid (65 deg. Baumé), 105 gal. per acre, on wheat sown the previous October.‡ So successful was the destruction of weeds

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* It should be added that acid of 65 deg. Baumé, as commonly used on the Continent, contains 90 per cent. of pure sulphuric acid, and is, therefore, stronger than the grade used in this country—*i.e.*, Brown Oil of Vitriol (B.O.V.), which is approximately 60 deg. Baumé and contains only 77 per cent. of pure acid. Solutions of the same percentage in France and England, therefore, would contain different quantities of pure acid. For example :—

French 8 per cent. sol., 65 deg. Baumé, 90 per cent. pure, would contain 7.2 per cent. pure acid.

English 8 per cent. sol., 60 deg. Baumé, 77 per cent. pure, would contain 6.16 per cent. pure acid.

Although for the most part we use the same percentages as the French, the actual content of pure sulphuric acid is lower, but has been found adequate.

† *Rabaté, E.* (1911.) Destruction des ravenelles par l'acide sulfurique. *Jour. d'Agric. Prat.*, XXI, (N.S.), pp. 407-9.

‡ *Blin, C.* (1925.) Essais de destruction des mauvaises herbes dans les céréales. *Jour. d'Agric. Prat.*, 43, pp. 338-40.

that many farmers began spraying, and in the single commune of Sancé they used nearly 2 tons of acid, spraying with the knapsacks thay have for dressing their vines.

Sulphuric acid is perhaps seldom used in relation to hoed crops, but in French trials both sugar beet and potatoes were sprayed in May, when Charlock had four to six leaves, and flowers were beginning to show on some plants.* Sugar beet in the seed-leaf stage was at first sprayed with a 1 per cent solution of acid (65 deg. Baumé), and then a 2 per cent. solution was tried, without appreciable result. Finally a 3 per cent. solution was used, 88 gal. per acre, and this gave complete destruction of the weed, the beet being without significant injury, so that six or seven days later it was held that the losses were almost nil. Potatoes were also sprayed with a 3 per cent. solution ; the Charlock was completely controlled, and though some potato leaves were scorched the plants soon recovered. It was thought that if the spraying had been done earlier when the weeds were small a 2 per cent. solution might have sufficed.

A bulletin issued by the Arizona Agricultural Experiment Station† recommends sulphuric acid spraying as " the quickest and cheapest method of weed control when acid and water are easily available, especially in places difficult to reach with farm machinery." It is observed that it kills rapidly, does not injure the soil, and is most effective when applied under pressure. Various strengths from 2 to 10 per cent. are indicated for use against many Arizona weeds.

In California a five per cent. solution of sulphuric acid at the rate of three gallons per square rod proved to be the cheapest effective contact spray for the control of St. John's Wort (*Hypericum perforatum*) applied at any flowering stage from the bud to the green seed.‡

Åslander § reported experiments that showed that sulphuric

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* *Morisset, C.* (1930.) Destruction des mauvaises herbes par l'acide sulfurique dilué. *Jour. d'Agric. Prat.*, 54, pp. 31-2.

† *Brown, T. G. and Streets, R. B.* (1928.) Sulphuric Acid Spray: A Practical Means for the Control of Weeds. *Ariz. Agric. Expt. Sta.*, Bull. 128, pp. 299-316.

‡ *Raynor, R. N.* (1937.) The Chemical Control of St. John's Wort. *Calif. Agric. Expt. Sta.*, Bull. 615, pp. 1-38.

§ *Åslander, A.* (1927.) Sulphuric Acid as a Weed Spray. *Jour. Agric. Res.*, XXXIV, pp. 1065-91.

acid gave the best result in dry air and at the higher temperatures, so that warm and dry weather is indicated as providing the most suitable conditions for spraying. Evaporation is then rapid, and the concentration of acid is increased, so that it continuously removes moisture from the weeds as water evaporates, quickly leading to collapse of the plants. Åslander lists upwards of 50 species of weeds reported by different authorities to be destroyed by sulphuric acid solutions of different strengths, varying from 3.5 to 10 per cent. Among these weeds are Charlock, Wild Radish, Shepherd's Purse, Goosefoot, Corn Marigold, Corn Chamomile, Stinking Mayweed, Nipplewort, Groundsel (Fig. 5), Sowthistle, Dodder, Wild Carrot, Cleavers, Poppies, Field Pepperwort (Fig. 11), Knotweed, Black Bindweed (Figs. 9, 12), Corn and other Buttercups, Spurrey, Chickweed, Penny Cress, Annual Nettle, and Bracken—surely a goodly array. Åslander's sources of information are very trustworthy.

In Gordon's experiments in Scotland (see p. 31) spraying with a 5 per cent. solution of sulphuric acid in June and again early in August was successful in destroying Bracken ; the grasses may be injured unless the canopy of Bracken is moderately dense, but they may be expected to recover.

According to a paper by Skilbeck and Coles* French experience indicates that solutions up to 20 per cent. by volume of acid can be used on wheat in spring without danger to the crop, but such a strength would not be employed in practice. It is customary to use weaker solutions on oats, barley and spring wheat than on winter wheat, and spraying usually takes place from March to May. It is said to be usual to top-dress with nitrate of soda a couple of weeks before spraying, or sometimes to give the nitrate in the spray solution, but never after spraying—though this does not conform with the suggestion of Rabaté given above. It is observed that the strength of the solution of acid (77 deg. Baumé) to destroy certain weeds is as follows : Charlock, Wild Radish, Chickweed, Grounsel, Speedwell, 5 to 7 per cent. by volume ; Poppy, 10 to 12 per cent. Corn Buttercup is severely checked, and in English trials "was completely annihilated by a 10 per cent. solution."

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* *Skilbeck, D. and Coles, H. G.* (1932.) Weed Control by Sulphuric Acid Spraying in France. *Scot. Jour. Agric.*, XV, pp. 410-14.

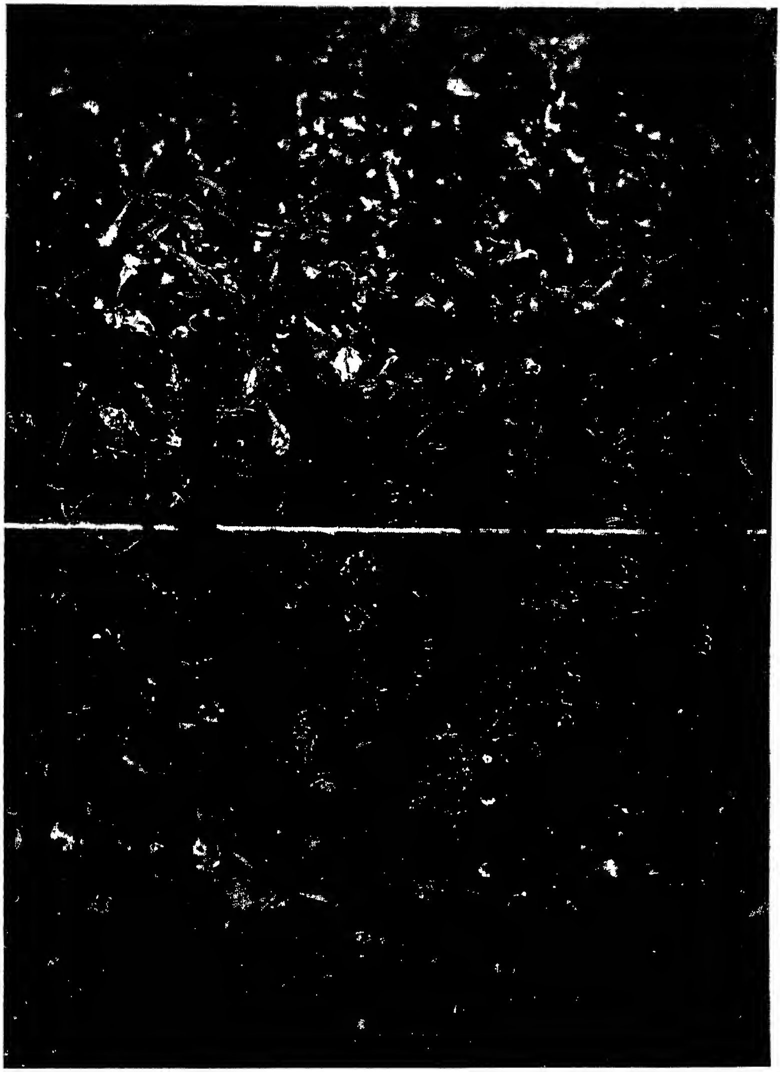

Photo lent by) (*Imper. Chem. Ind.*

Charlock Destruction. Photo taken 24 hr. after the Charlock (in Spring Oats) had been sprayed with a 9 per cent. solution of Sulphuric Acid (equal to 6.5 per cent. B.O.V. on a volume-volume basis). *Above*: Sprayed. *Below*: Unsprayed.

To face page 34.

PLATE X.

Photo lent by) (*Imper. Chem. Ind.*

Photograph taken a short time after the Corn Buttercup (in Winter Wheat) had been sprayed with a 13.5 per cent. solution of Sulphuric Acid (equal to 10 per cent B.O.V. on a volume-volume basis). *Left*: Sprayed. *Right*: Unsprayed.

Photo lent by) *(Nat. Sulph. Acid Assoc.*

(a)—Destruction of Charlock by spraying with Sulphuric Acid. *Right*: Sprayed. *Left*: Unsprayed.

Photo lent by) *(F. A. Pearson*

(b)—Destruction of Charlock by spraying with Copper Sulphate. *Left*: Winter Wheat not infested. *Right*: Spring Oats badly infested, sprayed with 30 lb. Copper Sulphate in 100 gal. water per acre. Control strip with Charlock in flower.

Photo lent by) (G. A. Cowie

(a)—Charlock Destruction with finely-ground Kainit. *Right*: 6 cwt. per acre. *Left*: Untreated.

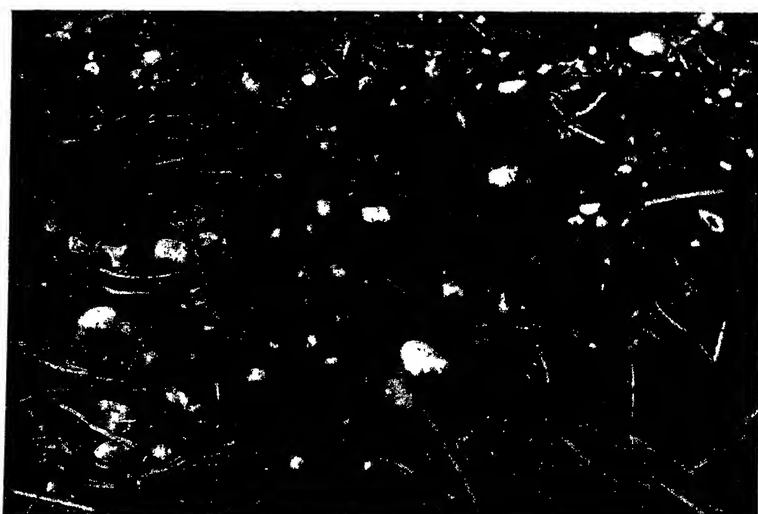

Photo lent by) (Imper. Chem. Ind.

(b)—Weed control by spraying fallow land in June and August with a 10 per cent. solution of Sodium Chlorate, at the rate of 100 gal. per acre. The land was badly infested with Creeping Thistle, and treatment resulted in over 90 per cent. control.

Spraying trials on the eradication of weeds in cereal crops by sulphuric acid and other compounds were carried out for several years by Imperial Chemical Industries at Jealott's Hill Research Station. These controlled experiments* corroborated much of the earlier work, indicating the varying resistance

FIG. 11.—Pepperwort (*Lepidium campestre* Br.), x about $\frac{2}{3}$; flower enlarged

FIG. 12.—Black Bindweed (*Polygonum convolvulus* L.) x $\frac{1}{2}$.

of different weeds to the acid, the increase in yield of crop that is usually obtained, with the possibility of depressed yields in very dry springs.

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* *Blackman, G. E. and Templeman, W. G.* (1936.) *J. Agric. Sci.*, XXVI, pp. 368–390.

Weeds can be effectively controlled in onion crops by spraying with B.O.V. at the rate of 13 gallons in 100 gallons of spray fluid per acre before the seedlings appear above the ground.* If more weeds appear a second spraying may be given when the plants are about 4 in. high, using about half the original strength of spray. A spreader of the sulphonated oil type is necessary for the first treatment, but should be omitted the second time.

Reference must also be made to a report issued in 1933 by R. K. MacDowall† who reviews the work done in spraying with sulphuric acid at home and abroad. In referring to the extensive spraying in France it is noted that many special spraying machines for the purpose are on the market. Experience has demonstrated that annual and biennial weeds are very freely destroyed. An account is given of trials in 1932. The cost at Shillingford (Oxon.) on 80 acres was 10s. per acre, about 70 per cent. of Wild Radish and 90 per cent. of Charlock being killed. The solution used was 8 to 10 per cent. by volume of acid (B.O.V. 77 per cent.),‡ 100 gal. per acre for Wild Radish and 77 gal. for Charlock. At Andover (Hants) the strength used was 7 to 7½ per cent., 80 to 120 gal. per acre, and the kill of Charlock was 100 per cent.

Mr. J. Barrow Simonds (Abbotts Barton Farm, Winchester) reported that he had had a limited experience of spraying with sulphuric acid. About 14 acres of spring oats were treated and Charlock was completely killed, while annual weeds generally were satisfactorily destroyed. Thistles and Docks were much burnt, but subsequently recovered. Mr. Simonds considered that his oats were too far advanced and were accordingly permanently checked—as spraying was followed by three weeks fine weather—and the weeds were less readily reached. He expressed the view, however, that the process was satisfactory, but that ideally the cereal should not be more than about 3 in. high, provided the weeds are ready for spraying. Even a week's delay may prevent success. He did not think the yield

* Weed Control in Onion Crops. *Advisory Leaflet* 309, Ministry of Agriculture, 1942.

† *MacDowall, R.K.* (1933.) Weed Destruction by Sulphuric Acid Spraying. *Inst. Res. Agric. Engin., Oxford*, pp. 36.

‡ See footnote * p. 32.

FIG. 13.—Persicaria or Redshank (*Polygonum persicaria* L.): *a* young seedling; *b* more advanced seedling; *c*, *d* flowering plant; *e* raceme of flowers. All x about ½.

of grain was affected, but that in his particular circumstances the straw was probably reduced.

Mr. J. F. Thompson (Malt House Farm, Ecchinswell, Newbury) wrote as follows :—

"I consider spraying with sulphuric acid one of the best investments I ever made. On my Burghclere Farm in May, 1933, I had eight acres of spring oats and six acres of barley so foul that I thought of ploughing them in. There would have been no crop worth harvesting. On May 31 the field was sprayed with sulphuric acid. All the Yellow Charlock and most of the White Charlock and 'Stinking Marigold' vanished in a few hours. The deeper-rooted weeds were severely checked. The corn looked yellow for a fortnight and then went ahead well. I harvested 60 sacks of oats, 44 sacks of barley and about 10 tons of *clean* straw, say £70 altogether, a very satisfactory return on the £11 spent on spraying."

"I also sprayed six acres of spring oats at Ecchinswell. Almost all the Charlock was killed, and the improved quality of the straw more than paid for the cost of spraying (£5). In this case I am not certain that the yield of corn was materially increased."

"We began with 7 per cent. of commercial sulphuric acid, and on the last two acres increased the strength to 10 per cent., which killed off all the White Charlock, even when in flower. In no case did the stronger mixture damage the corn. I shall insist on a 10 per cent. mixture next time I spray."

The foregoing notes refer to only a few of the great mass of records of successful spraying, but they are sufficiently conclusive to warrant any farmer in embarking upon a spraying campaign, where the conditions are suitable. Guidance may be obtained from the County War Agricultural Executive Committee. (Pls. IX, X, XI, (*a*)).

Spraying with sulphuric acid has recently been used not only to destroy weeds, but to arrest the "blowing" of light Fen soil by leaving the fields undisturbed as long as possible.* Spraying was done ten days after beet had been sown, before the crop had germinated. At least half the weeds, especially Chickweed, were destroyed or much checked by the spray, and the blowing of the soil was effectively hindered.

Bracken can be temporarily reduced by spraying with 100 gallons per acre of an 8 per cent. solution, but is apt to recur the following year.† The practical difficulties due to rough or hilly ground, and the transport of acid, water, personnel and equipment render the method uneconomic and apparently little better than cutting.

* Min. of Agric., Weekly News Service No. 252, July 3, 1944.

† Note from Prof. K. W. Braid. West of Scotland Agric. Coll., August 10, 1944.

It may be well to conclude reference to sulphuric acid spraying by noting a few points of importance and interest, in the light of present knowledge.

(1) Certain annuals and biennials can very definitely be sprayed with great success. Among them are Charlock, Wild Radish, Corn Buttercup, Spurrey, Poppies, Chickweed, Scarlet Pimpernel, Cleavers, Speedwell, Groundsel.

(2) Some perennials, such as Coltsfoot, Thistles and Docks receive leaf-damage and are severely checked.

(3) Grasses such as Slender Foxtail (Black Grass), Wild Oat and Couch are closely related to cereals and are not destroyed; the Wild Onion also remains unaffected.

(4) In general, sulphuric acid is not recommended for spraying any crops other than cereals, and any farmer who desires to make a trial is strongly advised to experiment with only a rod or so at first, and to take the expert advice of the War Agricultural Executive Committee.

(5) For the weeds mentioned under paragraph 1 above the strength of the solution should be as follows :—

Corn Buttercup—12 parts by volume Brown Oil of Vitriol to 88 parts of water (*i.e.*, 12 per cent. solution), using 100 gal. per acre.

Poppies—as for Corn Buttercup.

Wild Radish—10 parts B.O.V. to 90 parts of water, using 100 gal. per acre.

Charlock and the other weeds mentioned—7 parts B.O.V. in 93 parts of water, or up to 10 parts to 90 parts of water if weather conditions are cloudy or damp.

(6) In mixing, *water should never be poured into acid, but acid into water, slowly, and stirring steadily while this is being done.* This is most important, or the great affinity of the acid for water may lead to a dangerous accident.

(7) All water used should be pure and clean, free from sediment.

(8) "Seeds" may be sown on the third day after spraying; or spraying may take place after "seeds" are sown, provided seedlings have not yet appeared—say up to seven days after sowing.

(9) The time of spraying depends upon the age of the weeds; it should be when they are quite small, corresponding to the four-leaf stage in Charlock, and probably when the cereal is 3 to 7 in. high—generally between April 25 and June 10, depending upon the time of sowing, the kind of cereal, and the stand of the cereal at the time.

(10) While it is better to spray during fine and dry weather, spraying when dew is on the leaf is no great disadvantage; and slight rain following the day after spraying will not seriously affect results.

(11) All cereals may be sprayed with safety; any slight browning will quickly disappear.

(12) The soil is in no sense injured by the small quantity of acid applied.

(13) Arrangements may be made for spraying to be done by contract, if an inquiry is addressed to the County War Agricultural Committee. The cost may be from 12*s*. 6*d*. to 18*s*. 6*d*. or more per acre, the farmer supplying men and horses and carting water.

(14) Up to 20 acres may be done in a day by a horse-drawn machine, and on large farms the purchase of a machine for home use may be justified; or two or more farmers may co-operate to conduct their spraying as suits them best. A farmer who has a sufficient area to justify the purchase of a machine, or farmers who combine forces, may keep costs down to round about 10*s*. per acre, if the machine is fully employed.

VIII.—Sulphates of Copper and Iron

Copper and iron sulphates are sprays that eradicate weeds by poisoning, and have no direct fertilizing action on the crop. Many experiments have been made with both substances, and their use is often a matter of routine in farm practice, so that their efficiency is undoubted, provided always that weather conditions are favourable and the time and method of application well chosen.

Copper Sulphate.—Copper sulphate is chiefly associated with the destruction of Charlock and closely allied weeds, and in this country is used more widely than any other spray for the purpose. Before the war of 1914-18 so many controlled tests were made in various districts under different climatic conditions over a wide range of seasons, that it was possible to determine the best conditions for successful spraying. Climatic conditions influence the strength of the spray and the quantity needed per acre. In moist districts, as in Wales, heavier dressings and larger quantities per acre are needed for successful weed killing than in drier areas, as East Anglia. In East Anglia 50 gal. per acre of a 3 per cent. solution, or 40 gal. of a 4 per cent. solution, will usually be sufficient to kill ordinary rough-leaved Charlock, whereas in Wales and parts of Scotland at least 50 gal. of a 4 per cent. or 5 per cent. solution are necessary to obtain the same result.

Where Charlock is very plentiful a fairly safe rule is to increase the *quantity* of the solution, but not the strength, up to 75 to 100 gal. per acre, except during damp weather or in moist districts, when the *strength* of the solution, but not the quantity, should be raised. In some instances two successive treatments with 3 per cent. copper sulphate have eradicated Charlock much more thoroughly than a single spraying with double strength solution.* Charlock is most easily attacked when the flowering stems have been produced, but before the

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* *Wright, R. P.* (1904.) "Report on Experiments in 1901-3 on the Destruction of Charlock and Runch in the Oat Crop by Spraying." West Scot. Agric. Coll., Bull. No. 22, p. 43-61.

plants are in full flower or have formed any seed, but spraying would commonly then be less successful, since the crop would be high enough to protect the weeds too much and would itself suffer more. Spraying should be done when the plants are small, before they exceed 3 in. in height, but in the early rough-leaf stage if possible. (When Charlock is in the more advanced flat rosette stage the leaves are tough and resistant to the action of copper sulphate, so that stronger solutions are needed for success.) If water is difficult to obtain, treatment with finely-powdered copper sulphate may be quite effective* at the rate of 20 lb. per acre applied when the plants are just beginning to flower. Powdered silica or fuller's earth may be added to increase the bulk if the available spraying apparatus will not distribute evenly so small an amount as 20 lb. per acre. For dusting in this way, calm and settled weather is necessary, and the powder should be applied early in the morning when the leaves are wet with dew. (Pl. XI. (*b*)).

Smooth-leaved Charlock and Wild Radish are less effectively reduced by copper sulphate. The liquid runs off the waxy leaves of the smooth-leaved species, and two sprayings are often necessary where Wild Radish is troublesome.† Spurrey may be destroyed to some extent, but the results are uncertain. A strong solution (5 per cent.) is needed for a single spraying, but there is a risk of secondary growth springing up from the roots in time to flower and produce seed before harvest. Two sprayings with a 3½ per cent. solution may be fairly effective, but complete eradication by copper sulphate is not invariable with this weed. Poppies tend to throw off the spray, but if the plants are bruised they are then killed, and it has been suggested that rolling before spraying might prove effective. Some damage is done to the leaves and stems of Thistles and Docks, though these deep-rooted weeds cannot be eradicated by copper sulphate. Convolvulus,‡ on the other hand, seems to be quite resistant and is not reduced at all.

* ——— (1922.) "Destruction of Charlock." Min. Agric. and Fisheries, Leaflet 63.

† ——— "Spraying of Charlock among Corn Crops." Edin. and East of Scot. Agric. Coll. (1903), pp. 1-10.

‡ *Latshaw, W. L., and Zahnley, J. W.* (1927.) "Experiments with Sodium Chlorate and other Chemicals as Herbicides for Field Bindweed." *Jour. Agric. Res.*, Vol. 35, p. 759.

Hoary Pepperwort requires large quantities of a heavy dressing at the rate of 40 lb. of copper sulphate in 80 or 100 gal. per acre.*† The weaker spray, representing 24 lb. of copper sulphate in 60 or 80 gal. of water per acre, is of very little use as a simple spray, though 14 lb. per acre is a strong reinforcement to the killing action of sulphate of ammonia on this weed, as already shown in Section V.

If copper sulphate (blue vitriol) is used as a weed spray care should be taken to get it from a reliable firm, as it is easily adulterated with iron sulphate or green vitriol, which is much cheaper and much less effective, weight for weight. Copper sulphate may not be cheap, but it is easy and safe to use and the increase in crop resulting from the reduced weed competition usually ensures a considerably increased profit after all spraying and depreciation costs have been met. This increased profit may range from £1 to as much as £8 per acre in favourable circumstances.‡

The corrosive action of copper sulphate on metal must always be borne in mind and due care taken of the spraying machine. For the same reason the spray should be mixed in wooden vessels and stirred with wooden rods. To ensure rapid and complete solution the copper sulphate should be in powdered form, and not in crystals, as the latter take much longer to dissolve. As regards the crops, cereals are rarely damaged by copper sulphate sprays, though a slight temporary check may occur. Peas, beans, vetches and mangolds also recover satisfactorily from any preliminary injury, but turnips and swedes are destroyed as thoroughly as Charlock.

Iron Sulphate.—Iron sulphate may often be used to replace copper sulphate as a weed killer. The initial cost per ton is much less, but as four or five times as much iron sulphate is needed to achieve the same result, there is not usually very much difference in the final cost. Iron sulphate is less pleasant to work with, and has a certain disadvantage in that the fine

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* *Garrad, G. H.* (1923.) "Hoary Pepperwort or Thanet Weed." *Jour. Min. Agric.*, XXX, pp. 158-62.

† *Robson, R.* (1919-20.) "Control of the weeds. Whitlow Pepperwort and Black Mustard." *Jour. Min. Agric.*, XXVI, pp. 56-63.

‡ *Brenchley, W. E.* (1924-25.) "Spraying for Weed Eradication." *Jour. Bath and West and Southern Counties Soc.*, Fifth Ser., XIX, p. 18.

crystals do not keep well, while the large crystals take a considerable time to dissolve. The solution should be strained before use to prevent particles of grit entering the spraying machine and clogging the working parts. Under exceptional conditions of fine weather 15 per cent. may suffice, while in other circumstances as much as 30 per cent. may be needed, but a 20 per cent. solution represents a good average strength, at the rate of 100 lb. of iron sulphate in 40 gal. of water per acre.

The necessary weather conditions and the stage of growth the weeds should have reached before spraying are similar to those required with copper sulphate. Iron sulphate tends to act slowly,* and it may be three or four days before the weeds die. Consequently, if rain follows spraying and the solution is washed off too soon some at least of the plants may survive treatment. If the crop is rather far developed before spraying is done, iron sulphate has been found in Sweden to give better results than sulphuric acid, which is recommended for earlier dates. In Norway 680 spraying tests of iron sulphate with spring cereals showed an average increase of crop due to spraying of 23.6 per cent. of grain and 7 per cent. of straw.† The treatment was applied when the weeds had three or four leaves and the cereals were about 4 in. high. In spring wheat iron sulphate gave a greater increase in crop than any other of the methods of weed eradication tested, including various sprays and particular types of cultivation. Dry spraying or dusting with "Charlock powder" (about 60 per cent. iron sulphate and 40 per cent. gypsum) was the least satisfactory method, less than half the weeds being destroyed.

Iron sulphate spray kills Charlock‡ and also proves effective against such weeds as Poppy, Corn Cockle, Black Bindweed, Dock, Groundsel, Dandelion, Perennial Sow Thistle, Cornflower, Hoary Pepperwort, Thistles§ and Coltsfoot. On grass land, especially on lawns, Chickweed can be eradicated if spraying is done before the weed has made too much growth,

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* *Åslander, A.* (1930.) "Våra Viktigaste Åkerogräs och Metoder För Deras Utrotande." Bonniers, Stockholm, p. 109.

† *Korsmo, E.* (1932.) See p. 2.

‡ *Long, H. C.* (1928.) "Weeds of Arable Land, III," *Jour. Min. Agric.*, XXXV, p. 251.

§ ——— (1931.) "Thistles on Arable Land," Min. of Agric. and Fisheries, Advisory Leaflet No. 51, pp. 1-6.

and Dandelions can be reduced in the same way, but the deep-rooted habit of the latter demands so much poison to effect eradication that there is a risk of serious damage to the grass.

Recent experiments have proved the value of a mixture of sulphate of ammonia and sulphate of iron in reducing weeds on golf greens and lawns and keeping the turf in good condition. A mixture consisting of sulphate of ammonia 3 parts, calcined sulphate of iron 1 part, sand 20 parts* is recommended to be spread fortnightly during the growing season at the rate of 8 oz. per square yard. Another suggestion† is 3 lb. sulphate of ammonia with 6 lb. crystalline iron sulphate per 1,000 square feet, at fortnightly intervals from April to September; the dressings should be watered in, to avoid any scorching of the turf. While sulphate of ammonia reduces most weeds it encourages others like Pearlwort and Mouse-ear Chickweed, but these in their turn are killed by the sulphate of iron, which also increases the vigour of the fine grasses, especially Bents. (See also, however, Lawn Sands, p. 66.)

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* *Dawson, R. B., and Evans, T. W.* (1931.) "The Establishment, Maintenance and Renovation of Lawns." *Jour. Board Greenkeeping Res.*, II, No. 4, pp. 33-35.

† *Blackman, G. E.* (1932.) "An Ecological Study of Closely Cut Turf Treated with Ammonium and Ferrous Sulphates." *An. App. Biol.*, XIX, pp. 215-16.

IX.—Finely-Powdered Kainit

Quite a considerable number of trials during the last forty years have shown that finely-powdered kainit can be very successfully employed for the destruction of Charlock and some other weeds. This method, however, has been much less advocated of late, partly because of the many instances in which it has been inadvisedly or carelessly used; partly because a considerable quantity (5 or 6 cwt. per acre) has to be applied, making the treatment costly; and in part perhaps because cheaper and more effective materials have been introduced—notably sulphuric acid and calcium cyanamide—for use on soils not deficient in potash. Nevertheless, where a potash fertilizer is required, and ought to be given in any event, finely-powdered kainit may well be distributed at a time when it may be expected to do most injury to the weeds, especially Charlock, in cereal crops. (Pl. XII (a)).

The value of kainit for weed destruction is not very generally recognized, though it has been much recommended in Germany, where some 50,000 to nearly 80,000 tons have been used for this purpose annually. Kainit is usually broadcast in a dry state, but seldom applied as a wet spray; it acts by withdrawing water from the plant tissues, causing them gradually to wither and die. For this reason it cannot be used safely among broad-leaved leguminous crops, clovers, vetches, peas or beans, as it adheres to their leaves and injures the crop as well as the weeds, but with cereals, which are narrow-leaved, it causes little or no damage. Successful eradication depends on the kainit being in a very fine and dry state, and the products sold for the purpose contain a small proportion of a drier, such as kieselguhr or steamed bone flour, to keep the kainit dry and friable.

Comparatively heavy dressings used to be considered necessary, but nowadays 4 to 8 cwt. per acre are the practical limits when the material is freely available. Attempts to eradicate Spotted Medick with as little as 3½ cwt. per acre proved unsuccessful,* while with 10 cwt. or more per acre there

* *Fenton, E. W.* (1922.) "Spotted Medick." *Jour. Min. Agric.*, XXIX, pp. 643–48.

is a risk of injury to the crop. Heavy dressings of kainit tend to consolidate the surface of the soil and form a crust that needs breaking up, and a dressing of lime is often useful in such circumstances. For general use 6 cwt. of kainit per acre are recommended, of which one-half should be broadcast up and down and the other half across the field.* Weather is an important factor and, if possible, broadcasting should be done in warm, dry weather, in the early morning when the plants are wet with dew.. If rain follows too soon after application the anticipated weed reduction may not occur.

The benefit derived from the fertilizing value of the kainit depends largely upon the need of the soil for potash. In various English experiments, carried out under controlled conditions, little or no immediate crop increase was obtained by the use of kainit. In parts of Germany, on the other hand, where the need for potash manures is greater, larger increases of crop have been reported,† the grain and straw of oats being practically doubled. Kainit is specially effective in reducing Charlock and Wild Radish as young plants in the rosette stage, when they are less easily controlled by the usual strengths of copper sulphate sprays. The application of 640 lb. of kainit per acre applied to wet foliage may destroy up to 80 per cent. of Charlock, the results being most successful if the plants are wet and drying slowly.‡

For top-dressing barley kainit can be used satisfactorily as late as the first half of June, but for winter wheat application is recommended in February or March, and for spring wheat at the time of sprouting. Yellow Rattle has been much reduced in wheat and hay crops by a dressing of 6 cwt. of kainit per acre, and almost exterminated by 11cwt.,§ while Stinging Nettles have been cut down by the use of 15 per cent. kainit solution as a spray. Reports vary as to the efficacy of kainit in reducing

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* *Passmore, J. B.* (1925.) "Charlock Spraying in Devon." *Jour. Min. Agric.*, pp. 699-707.

† *Hofer,* (1931.) "Ein Beitrag zur Hederichbekämpfung." Die Ernährung der Pflanze, Bd. 27, Heft 6, pp. 171-2.

Strüber. (1933.) "Ein Hederichbekämpfungsversuch nach fünf Jahren." Die Ernährung der Pflanze, Bd. 29, Heft 6, pp. 105-6.

‡ *Bissey, R., and Butler, O.* (1930.) "Experiments on the Control of Mustard," *Amer. Soc. Agron.*, XXII, pp. 124-35.

§ *Furst.* (1931.) "Klappertopfbekämpfung durch Hederichkainit." Die Ernährung der Pflanze. Bd. 27, Heft 18, pp. 390-93.

other weeds, but Chickweed, Mayweed, Hardheads, Thistles, Speedwell and Nettles all suffer serious damage, whereas Spurrey, Fat Hen and Bindweed appear to be proof against injury with single dressings. In Holland, Bindweed, Nettles, Charlock and Chickweed were killed, and Poppies, Spurrey and Cranesbill damaged by the application of a first dressing of 900 lb. of kainit per acre, followed later by 200 lb., with a final dressing of 100 lb. for spots that may have been missed. The cost of such treatment is heavy, but might be borne in some cases on light soils where potash would be valuable as a fertilizer.

Mixtures of kainit or sylvinite with cyanamide in the proportion of 5 to 1, applied at the rate of 500—600 lb. per acre, have also given very satisfactory results both as weed killers and fertilizers. In Czecho-Slovakia* 540 lb. kainit and 135 lb. calcium cyanamide per acre proved effective in reducing bad infestations of Ox-eye Daisy and Cat's Ear (*Hypochaeris radicata*) on pasture land, the proportion of weed in the herbage falling from 52 to 8 per cent. within two years after treatment. Autumn and spring applications gave equally good results.

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* *Demela, J., and Brada, L.* (1936.) Hederich-Kainit als Unkrautvernichtungsmittel auf Wiesen. *Die Ernährung der Pflanze*, Bd. XXXII, pp. 105-8.

X.—Sodium and Potassium Chlorates

It would be difficult to give any very clear indication as to just how far these chlorates may be employed for weed destruction on the farm in Britain, partly because they may involve non-seeding of the land for some months, and partly because of their high cost. Nevertheless there is evidence to show that where land has become so overrun with weeds that it cannot be cropped for some time, until thoroughly cleaned at considerable cost, chlorates may be used to assist in weed destruction in association with cultural operations. For example, some time ago there came to notice a seven-acre field that was in very foul condition, and it received seven ploughings between January and autumn, as well as other cultural treatment, to get it fit for wheat. This was very costly, and it is quite likely that a dressing of sodium chlorate might have halved the cost of cultivations. Again, chlorates may be valuable for the treatment of paths and drives.*

It is to be emphasized that the use of chlorates requires considerable care, or there will be danger of fire and explosion, since these substances are highly inflammable when dry. For example, when solutions of chlorates have wetted the clothes of operators, the clothes should be washed out, or they may readily catch fire when matches are used or the wearer is very close to a fire. When solutions are used, therefore, it is well for the operators to wear overalls and rubber boots, since both may be washed. Leather boots may easily become wet, and prove risky when dried. Similar precautions are desirable when sacks, straw or other materials have become wet with the solution used. Several unpleasant accidents have occurred in the Dominions : in one instance an operator's leather boots suddenly ignited when he was close to a fire, and another operator's trousers that had become dry caught fire when he struck a match on them. Care should also be taken that

* *Tincker, M. A. H.* (1934.) Tests of Sodium Chlorate as a Garden Weed Killer at Wisley. *Jour. Roy. Hort. Soc.*, LIX, Part I, pp. 107-118.

neither the solid materials nor the solutions may be taken by live stock.

The fire hazard may be reduced by mixing other chemicals with the chlorate.* Calcium chloride, magnesium chloride and borax have all been used for this purpose, the commercial product Atlacide being a mixture of approximately two-thirds sodium chlorate and one-third calcium chloride.†

FIG. 14.—Ragwort (*Senecio jacobaea* L.), half nat. size.

Precautions are also necessary when chlorate is used to sterilize paths and other areas in nurseries and gardens, where it is the practice to stand out boxes and pots of plants. Many losses of tomatoes, chrysanthemums and bedding stuff have been traced to poisoning by chlorate taken up by the pots or boxes, on treated areas. The time that treated soil is likely to remain toxic depends on the type of soil and the water it receives. Unless the rainfall is high it appears that a dressing of ½ oz. per square yard will be toxic to plants for some months.‡

* *Cook, W. H.* (1933.) Fire Hazards in the Use of Oxidizing Agents as Herbicides. *Canadian Jour. Res.*, VIII, pp. 509-544.

† *Woodcock, J. W.* (1936.) Control of Ragwort with "Atlacide" as compared with Sodium Chlorate. *N.Z. Jour. Agric.*, LIII, pp. 65-8.

‡ *Owen, O.* (1937.) Note on the Use of Chlorate Weed Killers. *Jour. Min. Agric.*, XLIV, pp. 866-9.

PLATE XIII.

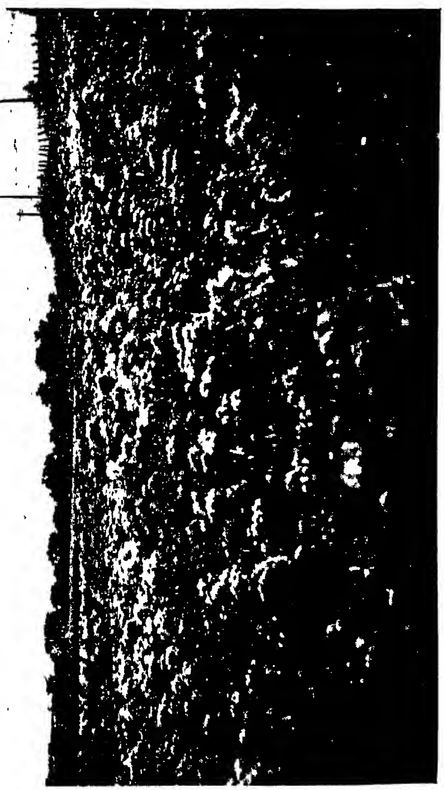

Photo copyright) (H. C. Long

A pasture infested with Ragwort (*Senecio jacobaea* L.)

To face page 50

Photo copyright) (*H. C Long*

a (left) Knotweed (*Polygonum aviculare* L.) ; *b* (above), Seedlings of Dock (*Rumex* sp.), nat. size.

Photo copyright) (*H. C. Long*

Photo lent by) (*Rothamsted Experimental Station*

Charlock Destruction. Barley sprayed with D.N.O.C. at rate of 100 gall. spray fluid per acre containing 6 lb. dry D.N.O.C. Left : Unsprayed. Right : Sprayed.

Photo lent by) *(Imperial Chemical Industries*

(a)—Effect of Methoxone on Broad-leaved Docks at three stages of development. Note contorted root system.

Photo lent by) *(Imperial Chemical Industries*

(b)—Experiment in Charlock Control. Note elimination of charlock on treated area by Methoxone applied at 1 lb. per acre.

Having said so much, it must be at once observed that chlorates have been the subject of extensive trials in many parts of the world, and it may be well to refer briefly to a few of the results obtained, and the conclusions to which the experimenters have come.

Trials in New Zealand, where Ragwort is a serious pest, have indicated that a light spraying with a 3 to 5 per cent. solution of sodium chlorate will kill this weed without serious injury to young grass, and it is suggested that this method is quicker and cheaper than cutting or pulling, and is definitely effective.* Subsequent work in New Zealand indicated that a 3 to 5 per cent. solution would give 100 per cent. kill of Ragwort ; and even 1 and 2 per cent. solutions were effective when the plants were near or at the flowering stage. A 5 per cent. solution was effective against Gorse.† Even more recently it was stated that "Where plants are nearing the flowering stage, or are in that stage, a 2 per cent. solution sprayed on is quite strong enough to give 100 per cent. of kills." The cost for 1 acre with a 5 per cent. solution was 9*s.* for the chlorate (4½d. per lb.), to which would need to be added local cost for labour. Badly infested land sprayed in December showed only one plant in March, and a splendid green growth of grass and clover.‡

In Tasmania a 7½ per cent. solution of sodium chlorate has proved 100 per cent. effective in destroying Ragwort, when used at the rate of 70 gal. per acre. The grass was not injured, and the cost of materials was 17*s.* 6*d.* per acre.§

Later tests in England showed that sodium chlorate gave the best control of Ragwort of all the substances tested. At the rate of 50-60 lb. per acre it gave an 88-100 per cent. control.**

Sodium chlorate is strongly commended†† for use on small areas only, the usual strength being a 10 per cent. solution (1 lb.

* *Deem, J. W.* (1930.) Control of Ragwort and Other Weeds by Spraying. *N.Z. Jour. Agric.*, XL, pp. 291-4.

† *Deem, J. W.* (1931.) Control of Weeds with Chlorates. *N.Z. Jour. Agric.*, XLIII, pp. 105-10.

‡ *Deem, J. W.* (1933.) Control of Ragwort on Grass Land. *N.Z. Jour. Agric.*, XLVII, pp. 99-104.

§ *Hicks, F. W.* (1930.) Chemical Control of Ragwort. *Tas. Jour. Agric.*, I, pp. 150-8.

** *Blackman, G. E.* (1938.) The Relative Toxicity of Chemical Weed Killers. *Ann. Appl. Biol.*, XXV, pp. 652-3.

†† *Willard, C. J.* (1930.) Killing Field Weeds with Chlorates. *Ohio Agric. Expt. Sta.*, Bi-monthly Bull. No. 146, pp. 158-68.

per gal. of water). To kill out Couch and Creeping Thistle, one, two or three further sprayings may be necessary: only rarely has the Ohio Station succeeded in completely eradicating these two weeds at one application with less than 4 lb. per rod (5¾ cwt. per acre nearly). At the rate of 1 lb. in 2 gal. per square rod Ox-eye Daisy was completely killed without materially injuring grass.

Another American report states that in the four years 1927-30 nearly 2½ million pounds of chlorates were used in Idaho for commercial eradication of perennial weeds, with generally satisfactory results. At the rate of 160 lb. per acre in the summer and autumn of 1930 sodium chlorate was very successful against Field Bindweed, securing 100 per cent. kill by mid-September, 1931.* The expense of chlorate may prove a disadvantage for some purposes, as with Perennial Sow Thistle, Creeping Thistle and Bindweed effective chlorate treatment cost four to eight times more than eradication by tillage.† Chlorates in 10 per cent. solution applied at about 100 gal. per acre have proved effective in destroying some less ordinary perennial weeds which are locally troublesome. Ramsons, Woodwax, Buttercup and Horseradish have been thus destroyed, but Wild Onion was not killed even by the strongest solution tested.‡

In Scotland, spraying with a 1 per cent. solution of sodium chlorate (80 gal. per acre) in 1928 killed all vegetation, including bracken fronds. Generally, 2 cwt. of sodium chlorate per acre proved necessary to destroy bracken, at a prohibitive cost for large areas. A scythe attachment has been devised whereby a solution of chlorate can be smeared over the cut ends of the bracken with a self-feeding rubber pad, utilizing less than 20 lb. sodium chlorate per acre in solution. This kills the underground parts by translocation downwards through the cut ends of the plant tissues.§

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* *Hulbert, H. W., Bristol, R. S., and Benjamin, L. V.* (1931.) Methods Affecting the Efficiency of Chlorate Weed Killers. *Idaho Agric Expt. Sta.*, Bull. 189, pp. 12.

† *Tingey, D. C.* (1934.) The Comparative Cost and Effectiveness of Tillage and Chlorates in the Control of Morning Glory, Canada Thistle and Perennial Sow Thistle. *Jour. Amer. Soc. Agron.*, XXVI, pp. 864-76.

‡ *Rees, J.* (1938.) The Use of Sodium Chlorate in Destroying Some Perennial Weeds. *Welsh J. Agric.*, XIV, pp. 277-80.

§ *Bates, G. H.* (1940.) *British Rubber Publicity Association*, Rubber and Agric. Ser. Bull. No. 14, pp. 1-4.

In view of the danger of accidental firing it is wise to burn off all bracken sprayed with chlorate as soon as it is sufficiently dry.*

Chickweed in a potato crop, and Chickweed and Groundsel on an area of recently planted bulbs, near King's Lynn, were sprayed in September and October, 1932, with 1 and 2 per cent. solutions of sodium chlorate, 80 gal. per acre. There was a perfect kill in each instance. There was no danger to the unlifted tubers or to the bulbs, and wheat drilled on the potato land eight weeks after spraying grew normally and vigorously.†

In Scottish experiments, reported by Clouston and Hill, 15 per cent. and downward solutions of sodium chlorate, and generally 2½ per cent. solutions of potassium chlorate, were used. It was found that the minimum effective dressings of sodium chlorate per acre to destroy certain weeds were as follows: Chickweed, 15 lb.; Grounsel, 30 lb.; Creeping Buttercup, 50 lb.; Knotweed, 100 lb.; Coltsfoot and Great Stinging Nettle, 150 lb.; Couch, 150-200 lb.; Creeping Thistle, 250-350 lb., depending upon the soil, size of plants and amount of grass; Creeping Thistle, land ploughed before application, 200 lb.; Sheep's Sorrel and Docks, very resistant, 400 lb.—200 lb. first and then 100 lb. twice at intervals of a month; Goutweed, very resistant, 500 lb. and then not entirely killed out. It is stated that 1½ to 2 cwt. per acre as a 5 per cent. solution (1½-2 cwt. in 336-448 gal.) is a good general dressing. The sodium and potassium chlorates cost 30*s.* and 33*s.* per cwt. respectively, but later rose to about 40*s.*‡ for each. The high cost of the larger applications would, of course, be generally prohibitive.

In some areas Goutweed can be killed out with 250-350 lb. sodium chlorate per acre, if it is first sprayed with 1 cwt. per acre and then "spot treated" once or twice more. K.W. Braid (Scotland) found Sorrels much more resistant than Goutweed. Season affects the efficiency of chlorate, as in wet areas especially it is of very limited use during the winter months or

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* *Braid, K. W.* (1941.) Weed Killers for Fields and Gardens. *Jour. West of Scot. Agric. Coll.*, Former Students' Club, pp.8.

† *Bates, G. H.* (1933.) *Farmer and Stockbreeder*, Feb. 27.

‡ *Clouston, D. and Hill, A.* (1933.) The Use of Chlorates in Weed Control. *Trans. Highland and Agric. Soc. Scotland*, XLV, pp. 128-135.

Ibid. (1933.) The Use of Chlorates as Weed Eradicators. *Scot. Jour. Agric.*, XVI, pp. 196-208.

in shaded areas. Chlorate appears to be most effective when the transpiration rate is high.

Trials were conducted in 1931 on a farm in Herefordshire, on 8 acres carrying 40 species of weed, with a preponderance of Docks. Sodium chlorate was applied both broadcast and in solution, and part of the area was a control and part devoted to cultural cleaning. No less than 91 per cent of the area was occupied by the weeds, the remaining 9 per cent. being bare ground. Docks, Buttercups and Creeping Thistle together occupied 40 per cent. of the area; Broad-leaved Plantain, Couch, Common Bent and Field Bindweed a further 21 per cent. and other weeds 30 per cent. The sodium chlorate was applied at the rate of 2 cwt. per acre in the last week of October, and the plots were examined in the following April, June and October. The earlier examinations showed that the Buttercups were killed, and " there had undoubtedly been a good control of weeds." By October it was found that the Couch and Bent had been eradicated, as well as shallow-rooted annuals; the Creeping Thistle was reduced to a few scattered plants; but Docks and Bindweed were still growing strongly, and Dandelions were recovering from the set-back. The conclusion was that:—

> "Sodium chlorate, applied in the autumn, at the rate of 2 cwt. per acre, to very weedy land of the heavy loam type, and used in conjunction with the usual cultural operations for the control of weeds, will bring about the eradication of Couch Grass, Creeping Bent Grass, Crowfoot and shallow-rooted annuals."

The cost of materials was £2 10*s.* per acre, and the cost of application 15*s.*—total £3 5*s.*, plus cost of usual cleaning. The control area, however, cost £4 per acre for ordinary cleaning, and at the end of the season was far worse than the treated area.*

Docks in seed clover were effectively destroyed by hand labour, placing a pinch of sodium chlorate in the centre of each dock so as to avoid damage to the clover. The work took one man a week, at a total cost of about 7*s.* 6*d.* per acre.†

* *Ling, A. W., and Haggard, A.* (1933.) The Eradication of Weeds of Arable Land by Sodium Chlorate. *Jour. Min. Agric.*, XL, pp. 224-8.

† *Barnardiston, E.* (1938.) Destruction of Weeds in Seed Clover with Sodium Chlorate. *Jour. Min. Agric.*, XLV, pp. 5-6.

Since the first edition of this book appeared a great deal of work has been done on the value of chlorate as a weed killer, and much information has been published. Even now, however, it still seems that we do not know sufficient about the effect of chlorates for general farm purposes under British conditions of climate. Nor is their practical value evident in view of their high cost, the cost of labour, and the routine of the farm, to say nothing of the prices of farm produce—for when prices are low, heavy expenditure is not warranted, even for weed destruction.

Further and thorough trials are needed, not so much with large quantities per acre, as to determine whether rather small amounts in solution may not often prove of value to control annual weeds, and increased amounts within practical limits of equal value—say during bare fallows—to destroy many perennials. It is possible that, as implied by M. Fron and Mlle. Bertrand,* quite weak solutions of sodium and potassium chlorates might be used with safety to spray cereal crops for destroying certain annuals, as they found with wheat containing a considerable quantity of Corn Buttercup. It may be expected that extended use of chlorates for weed destruction would result in a reduction in their price to meet the demand. (Pl. XII (*b*)).

The importance of sodium chlorate for certain purposes is well summed up in a report from the Wisley Laboratory,† which is here quoted :—

> "Considering all the available evidence, sodium chlorate is recommended as a weed killer for garden paths, neglected plots, and for the eradication of certain troublesome weeds. Whilst the chemical may be used as a dry powder, its use is particularly recommended as safer in solution, of concentration 2½ per cent. for small weeds, 5½ per cent. for herbaceous weeds, and 10 per cent. for particularly troublesome weeds, with deeper rootstocks, at the rate of application of 1 gallon to 10 square yards. The weed killer is decomposed in the soil and planting may safely take place after an interval of 4 to 6 months, and in many cases even earlier. Early autumnal application is most likely to prove convenient and remunerative; the plants to be destroyed should be growing vegetatively (*i.e.*, in leaf.")

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* *Fron, G.* (1933.) Le Chlorate et la Déstruction des Rénoncules. *Jour. d'Agric. Prat.*, LX, pp. 499-501.

† See * p. 49.

XI.—Compounds of Arsenic

Arsenic compounds are best known as sprays for fruit trees and as weed killers on paths, for which they are very valuable. In view of their dangerously poisonous properties for human beings and animals, however, many attempts have been made to find efficient substitutes, but for the purposes mentioned they still hold their own. In agricultural practice in this country so many chemicals and fertilizers are recognized as effective for weed reduction that arsenical compounds are seldom considered, and are rarely, if ever, recommended. In California, however, where "deep-rooted" weeds, such as Bindweed, are specially troublesome in some areas, a heavy dressing of sodium arsenite has been found to kill 85 to 90 per cent. of Bindweed, but not to eliminate it.* All other vegetation perished and the land remained barren for at least 14 months afterwards. Later experiments† claim that if the solutions are acidified with sulphuric acid the weed killing is more complete and no permanent injury is done to the crop-bearing powers of the soil. The use of this method is somewhat limited by the poisonous and corrosive properties of the constituents, and by the fact that the weeds must be mature and must be sprayed at night if they are to be effectively destroyed.‡

Two lb. of sodium arsenite in 52 gal. of water per acre (about ½ per cent.) is said to have been effective against Thistles and Bracken.§ The preparation of the solution needs special care, as the powdered arsenite is dangerous to health if inhaled.

* *Gray, G. P.* (1919.) "Tests of Chemical Means for the Control of Weeds." Univ. Calif. Pubs., 4, No. 2, pp. 67-87.

† *Crafts, A. S.* (1933.) "The Use of Arsenical Compounds in the Control of Deep-rooted Perennial Weeds." *Hilgardia*, 7, pp. 361-72. See also 8, pp. 125-147.

‡ *Crafts, A. S.* (1937.) The Acid-arsenical Method in Weed Control. *J. Amer. Soc. Agron.*, XXIX, pp. 934-943.

§ *Adams, J.* (1917-18) "The Use of Chemical Sprays for Combating Weeds." Ann. Rept. Quebec Soc. Protect. Plants from Insects and Fungous Diseases, 10, pp. 70-78.

Stronger solutions, 2½ per cent. and 5 per cent., were used in France to destroy Wild Radish,* but the oats were also seriously damaged and the crop much reduced. Sodium arsenite has, however, proved very useful among such crops as rubber, sugar cane and pineapples in countries where growth is so rapid that weed control is essential for success. Where the crops themselves are sensitive to arsenic the spraying machines are sometimes hooded to protect the crops and concentrate the poison on the weeds in the intermediate spaces. For annual weeds arsenical sprays are effective over a wide range of concentrations, and they are injurious to all stages of growth. Broad-leaved crops, such as lucerne and clover, are usually injured by arsenical sprays, though in South Africa a solution of ½ lb. of arsenite of soda in 5 gal. of water has been found satisfactory for the destruction of Dodder in lucerne, without damage to the crop.†

Apart from its poisonous properties, arsenite of soda tends to change for the worse the mechanical condition of the soil, while it is strongly held and is not easily washed out by heavy rains: if used too freely the soil may be poisoned for subsequent crops. Sodium arsenate at 10 lb. per acre, repeated at 7-day intervals, appeared to have no harmful effect on the soil in Malay.‡ Beans and cucumbers are very susceptible to arsenic in the soil, whereas cereals and grasses are more resistant.§ This fact has been turned to advantage in New Zealand for the improvement of lawns and golf greens. Most of the weeds and the clovers can be killed out by spraying with 1 lb. of arsenic pentoxide in about 8 gal. of water, at the rate of 240 gal. per acre, ** though a second spraying may be necessary about three weeks after the first. Large bare areas are inevitably left, but as the arsenic pentoxide rapidly changes

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* *Rabaté, E.* (1927). "La Destruction des Mauvaises Herbes." *L'Agric. Pratique*, Lib. de l'Acad. d'Agric., Paris, p. 38.

† ——— (1908.) "Eradication of Dodder." *Jour. Bd. Agric.*, XV, pp. 280-1.

‡ *Greig, J. L.* (1937.) The Use of Chemicals for the Eradication of Lalang Grass. *Malay Agric. Jour.*, XXV, pp. 363-9.

§ *Morris, H.E., and Swingle, D. B.* (1927) "Injury to Growing Crops caused by the Application of Arsenical Compounds to the Soil." *Jour. Agric. Res.*, 34, No. 1, pp. 59-78.

** *Bruce Levy, E., and Madden, E. A.* (1931.) "Weeds in Lawns and Greens." *N.Z. Jour. Agric.*, Vol. 42, No. 6, pp. 406-21.

into a non-injurious compound in the soil, these spaces can be raked over and re-seeded two or three weeks after the last spraying. The grass is discoloured for a time, but as the main spraying is often done in autumn when the sward is turning brown naturally, this is a minor disadvantage. The chief difficulty is the recurrence of weeds from the stores of seeds lying in the soil. The competition of healthy, strong-growing grass will do much to kill off fresh weed seedlings, but otherwise constant vigilance is necessary to prevent the weeds regaining their former position. Attempts have been made to kill the seeds in the soil by top dressings with lead arsenate,* from 10 to 100 lb. per 1,000 square feet, but this did not prevent the germination of weeds nor the growth of seedlings of a number of common lawn weeds.

Arsenic pentoxide has been used effectively to control Ragwort in pastures, infested areas being sprayed with a solution of 1 lb. in 5 gal. of water, the best time being in spring when the plants are in the rosette stage.†

On the whole, therefore, in this country arsenical sprays are not of great importance in ordinary farm economics, though occasions may arise when they are of greater value than other herbicides.

* *Muenscher, W. C.* (1930.) "Lead-Arsenate Experiments on the Germination of Weed Seeds." Cornell Univ. Agric. Expt. Sta., Ithaca, Bull. 508, pp. 3-10.

† *Prunster, R. W.* (1940.) Notes on the Control of Blackberry, Watsonia, Bracken and Ragwort in Victoria. *Jour. Counc. Indust. Res.*, Vol. XIII, pp. 178-80.

XII.—Di-nitro-ortho-cresol and its Derivatives

Among the many chemical compounds that have in recent years been tested for their herbicidal value di-nitro-ortho-cresol (D.N.O.C.) and its derivatives must be regarded as very promising for the purpose. D.N.O.C. is a yellow dye derived from the by-products of coal distillation. It is not very soluble, but its derivatives, also dyes, are readily so, and are therefore more suitable as weed killers. As the material is inflammable when dry it is marketed in the form of a paste with a specific percentage of water.

Sodium di-nitro-ortho-cresylate, under the name Sinox, was first developed as a herbicide in France in 1933, and introduced into the United States four years later. It proved very efficient, and 20,000 acres in California were sprayed with Sinox in 1941, and similar acreages in successive years.

Sinox is highly toxic and very selective, its properties being enhanced by the addition of an activator such as ammonium sulphate or sodium bisulphate. (The latter is advised where there is danger of extra nitrogen causing lodging in cereals.) The rate of application of Sinox and of activator varies with the crop and the weeds against which treatment is directed. A usual rate is 1 gal. of Sinox in 100 gal. of water, per acre, for Charlock among cereals. Other weeds, such as Wild Radish, Knot Grass, Lamb's Quarters and Chickweed, are more resistant and need heavier doses. In such instances it is essential to attack the weeds in the early seedling stages, as older plants require a dosage of Sinox that may very seriously damage the crop.

In New Zealand a 2 per cent. solution of Sinox in water at the rate of 100 gal. per acre gave virtually a complete kill of Fat Hen, Wire Weed, and Black Bindweed seedlings in linen flax, without injury to the flax when the latter was 4 in. to 5 in. high.* Later on, however, more weeds appeared from seeds

* *Black, M. A.* (1944.) "Sinox: A Selective Weed Killer for Controlling Weeds in Linen Flax." *N.Z. Jour. Sci. and Tech.*, 25, Sec. A, pp. 235-241.

lying dormant in the soil, so that a single spraying was insufficient to give a clean crop.

Care is needed when Sinox is used on leguminous crops. Biennial sweet clover seedlings are very susceptible to injury by Sinox at all rates of application, and at all stages of growth of the crop. Lucerne and red clover seedlings are markedly more tolerant and develop a high resistance at the age of about 5 to 6 weeks. Yields of oats, barley, and flax were much increased in American trials by the reduction in weed competition resulting from Sinox spraying. Wild Mustard, Wild Buckwheat, Lamb's Quarters and other broad-leaved weeds were found to be well controlled by 80-100 gal. of 1 per cent. Sinox solution per acre if applied when the weeds had from 3 to 7 leaves.*

Spraying with Sinox may prove ineffective if the temperature is too low at the time or if the weather has previously been cold or extremely dry. This difficulty is surmounted when an activator is used. The killing action of the spray may be rather slow, but the material is not easily washed off even if rain follows soon after application. One great advantage of Sinox is that it has no damaging effect on the soil, as it is decomposed by micro-organisms without leaving any toxic residues.

At the time of writing Sinox is unobtainable in this country, but similar compounds have been developed and may prove very valuable as they become better known and conditions of application have been determined. Sodium and copper salts are both marketed, under the names Sodinoc and Cudinoc, the use of ammonium sulphate again being recommended with the former at the rate of 10 to 20 lb. per acre.

D.N.O.C. paste does not need an activator. The important thing to ascertain is how the various crops are affected by different strengths of the spray. Cereals soon recover from any initial damage due to spraying, and it is claimed that beans and peas are also resistant, but small-scale tests at Rothamsted suggest that the bean crop may be reduced by the use of Sodinoc at 7½lb. dry matter per acre and Cudinoc at 5 lb. dry matter per acre. With flax (linseed) this strength of Cudinoc

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* *Schwendiman, A., Torrie, J. H., and Briggs, G. M.* (1943.) *Jour. Amer. Soc. Agron.*, XXXV, pp. 901-908.

and D.N.O.C. at 6 lb. dry matter per acre completely destroyed the crop, whereas with Sodinoc at 7½ lb. quite a good stand was obtained, though ripening was somewhat delayed. It also seems unlikely that sugar beet seedlings will stand up to the spray.

The sodium salt of di-nitro-ortho-cresol was successfully used in 1943 by the Edinburgh and East of Scotland Agricultural College for controlling Charlock in oats, when the weed was in the early bud stage and the cereal 6—8 in. high. Dilutions of 0.5 per cent. and 1 per cent., and 0.5 per cent. with the addition of 1 per cent. sulphate of ammonia, all destroyed the Charlock with little or no damage to the cereal.

As all these materials are dyes they stain yellow everything with which they come into contact, so that protective clothing is necessary, especially if spraying has to be done in windy weather. Wild Radish, Lady's Mantle (*Alchemilla arvensis*), Mayweed, Thistle, and Annual Poa all proved resistant to the sprays as used, though the Annual Poa may have grown up after spraying, from seeds buried in the soil.

Among cereals, at least, spraying can be done successfully at various times in the growth of the crop. If the main object is to increase yield by reducing the competition between weed and crop, spraying when the weeds are in the seedling stage is the best. If, however, it is desired to reduce the quantity of weed seeds in the harvested grain, it has been suggested that later spraying may be the more effective, as with Charlock. Normally, early spraying is to be advocated, as many weeds are susceptible to attack in their seedling stages, but harden off and become resistant as they get older. (Pl. XV).

In view of the French and American experience, di-nitro-ortho-cresol and its derivatives deserve fuller investigation and widespread trials, if only because of their relative harmlessness to human beings coupled with their great toxicity and selectivity to plants. These derivatives are receiving the special attention of the Agricultural Research Council, whose investigations and findings are given in the Appendix, p. 74.

XIII.—Methoxone.

The most recent development in weed control promises to be of considerable significance. Work on plant hormones or growth-promoting substances, and their possible use for growth-stimulation of commercial crops, has resulted in an unexpected change of direction in research.

Two of the first synthetic plant hormones, *a*-naphthylacetic acid and *b*-indolylacetic acid, were found to have stimulating effects on the root systems of herbaceous cuttings. It was also found that increasing concentrations had variable effects on different plant species, and that certain families showed greater response to the growth stimulus than others. If this stimulus is exaggerated it is possible to kill some species while neighbouring plants of other species are undamaged. The *Gramineae*, for instance, are practically unaffected by many of the growth-promoting hormones while the *Brassicae* are extremely susceptible.

As a result of the work carried out by W. G. Templeman and W. A. Sexton at Jealott's Hill Research Station a range of phenoxyacetic acid products were discovered, of which Methoxone (4-chlor-2-methylphenoxyacetic acid) was finally chosen as being a most efficient weed killer with selective properties.

The action of these products involves a new principle in weed control. Most weed killers act by destruction of the leaf tissue by corrosive action. The new products are absorbed by the leaves and roots, and in those plants that are susceptible to the growth stimulus violent physiological disturbance takes place in the plant structure, resulting in abnormal development and contortion. The stems swell and sometimes burst and the plant finally dies, but the process is not rapid and may extend over several weeks. Plants like the cereals, that do not respond to the growth stimulus, are unharmed (Pl. XVI (a)).

The amounts of the active principle required to achieve success are extremely small, and 4 oz. Methoxone per acre have

given a complete kill of Charlock, but for practical reasons the usual rates of application are from 1 lb. to 2 lb. per acre on cereal crops. As such small quantities cannot be applied evenly without considerable dilution Methoxone is marketed under the trade name " Agroxone " as a dilute powder or in solution, for application to the land by fertilizer distributors or spraying machinery respectively. (Pl. XVI (*b*)).

It must be remembered that this development is only in its initial stages, and that further research may result in far-reaching discoveries. Extensive experimental work in 1945 showed that various weeds in cereals and grass land were affected by Methoxone in the following order of susceptibility :

Complete Control	*Seriously affected*	*Affected*	*Unaffected*
Yellow Charlock	Corn Marigold	Bindweed	Bladder Campion
Wild Radish	Fat Hen	Spurrey	Coltsfoot
Pennycress	Speedwell	Thistles	Cleavers
Corn Buttercup	Chickweed	Mayweed	
	Poppy	Polygonum spp.	
	Sow Thistle	Dock	

Special care will need to be taken that such potent materials are not applied, by accident or design, to susceptible plants that are not weeds. For instance, the deadly effect upon Yellow Charlock indicates the danger of allowing these new weed killers to drift over any cultivated crops of the cabbage family.*†

Most of the experimental work so far has been in connection with weeds in cereal crops. The work is being extended to grass land, and it is already clear that some of the worst weeds, such as Creeping Buttercup, are controllable by this means, and there is every reason to believe that the method will be effective against Dandelion, Daisy and Plantain, which cause so much trouble on lawns and sports grounds.

* *Blackman, G. E.* (1946). Weed Control in Cereals by Chemical Methods. *Jour. Min. Agric.*, LIII, pp. 16—22. (See Appendix, p. 74).

† *Hudson, H. G.* (1946). Weed Control in Norfolk. *Jour. Min. Agric.*, LIII, pp. 22—27.

XIV.—Miscellaneous

Salt.—Salt has been recognized as a weed killer for many years, for it has long been used to reduce weeds on paths, and the value of its application on the cut stumps of certain weeds is by no means a recent discovery. From the agricultural point of view the use of salt presents certain difficulties that call for special consideration. To be effective, either dry or in solution, considerable quantities are usually necessary, but unfortunately the accumulation of salt in the soil beyond a certain point tends to hinder the growth of crop plants. If, however, the salt is washed out of the surface soil by rain it often seems that plant growth is stimulated, and the development of weeds in succeeding years is extra strong. If this is realized, however, salt can on occasion be most useful in weed eradication.

French work* indicates that a strong solution containing 55-66 lb. of salt to 22 gal. of water is very effective if applied to cereals during the period of active growth before the weeds flower, and that the cereal crop is quite unharmed. About 150-200 gal. per acre are needed, and success or failure is very dependent upon the weather and temperature conditions. The action of salt is slow, and several days elapse before any result is seen. Consequently a period of fine, dry weather is needed, warm enough to encourage rapid growth, as the weeds are then most susceptible. Wild Radish and Charlock can be completely destroyed, and Knotgrass, Bindweed, Chicory, Vetches, Chickweed, Buttercups and others severely scorched. Blackberry, Thistles and Bracken are also recorded as being reduced by similar treatment in Canada and the United States, though in some areas it has been found necessary to spray bracken twice in the year.†‡

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* *Rabaté, E.* (1927.) pp. 64-69. See ref. * p. 57.

† *Adams, J.* (1917-18.) See ref. § p. 56.

‡ *Cox, H. R.* (1936.) Eradication of Ferns from Pasture Lands in the Eastern United States. *U.S. Dept. Agric.*, Far. Bull. 687, p. 8.

Where Bindweed is troublesome in small patches dry salt can be used at the rate of ½-1 lb. per square foot, a second application being given if necessary, though this treatment renders the spots barren for several seasons after. This sterilizing action of salt can be turned to account on roadsides, paths and similar areas, where as much as 2 to 6 tons per acre have been utilized to kill deep-rooted weeds.* On paths 1 lb. per 100 square ft.† (4 cwt. per acre) will kill small grass weeds, but has little effect when the plants are larger. Towards the end of the season the beneficial effect appears to be lost and the weeds often spring up again in increased numbers.

On grass land, however, the subsequent barrenness is not desired, and very judicious treatment is needed. Patches of nettles may be dealt with by cutting in spring and then dusting with salt at 5½ lb. per rod, or 6-7 cwt. per acre.‡ Yellow Rattle in pastures can be heavily reduced by 6 cwt. salt per acre applied when the weed seeds are just germinating, about the third week in April in early districts. Later applications and smaller doses (3 cwt. per acre) are much less effective. Reports vary as to the after-effects on the grass crop, as the salt may prove injurious, especially when April dressings are followed by frosty mornings and bright sunshine.§ On a small scale salt is useful for destroying Dandelions in lawns, when applied to individual plants, either dry at the rate of one teaspoonful to each cut surface, or in a solution of 1 lb. of salt in three pints of water, at the rate of two tablespoonfuls per plant.

On the whole, salt is too uncertain and risky in its action to be generally recommended as a weed killer, except on areas where subsequent barrenness does not matter and sufficiently heavy dressings can be used to prevent a fresh crop of weeds springing up within a short period.

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* *Rudolfs, W.* (1921.) Experiments with common Rock Salt: II. Eradication of Weeds and Cleaning of Roadsides with Salt. *Soil Sci.*, XII, No. 6, pp. 457-470.

† *Hill, A.* (1928.) "Trials of Weed Killers on Garden Paths." *N. Scot. Coll. Agric.*, Bull. No. 35.

‡ *Bates, G. H.* (1933.) "The Distribution and Control of the Great Stinging Nettle." *Jour. Min. Agric.*, XXXIX, No. 10, pp. 912-22.

§ ——— (1918.) "Yellow Rattle on Palace Leas." *Cockle Park, Guide to Expts.*, Abs. Durham Univ. Dept. Agric., Cockle Park Rept. and Bulls., 1914-1920, p. 33.

——— (1917-1919.) "The Eradication of Yellow Rattle." *Repts. on Expts.*, Univ. Coll. N. Wales, Bangor, p. 21.

Lawn Sands.—The improvement of lawns, with special reference to eradicating Plantains, Daisies, Dandelions and their relatives, Selfheal, Creeping Buttercup, and other species, often depends upon surface treatment to open the soil to water and air and the proper assimilation of fertilizers applied. Regular mowing will go far to reduce weeds, provided that the grasses can be induced to grow densely and strongly. To this end treatment with fertilizers may often be essential to success. Reliable work has shown that dressings with a mixture of sulphate of ammonia and sulphate of iron will often have a remarkable effect in reducing weeds on lawns, especially the broad-leaved species. This has been demonstrated at Jealott's Hill.

> "The almost marvellous effect of "lawn sands" in reducing many weeds of lawns, such as Daisies, Plantains and Dandelions, has been the subject of comment for a quarter of a century. The basis of these substances would appear to be sulphate of ammonia, together with some sulphate of iron, finely powdered and mixed with sand for convenience of application. It is possible to make use of the principle more cheaply by purchasing the two chief ingredients separately and mixing them with a distributable quantity of fine dry soil or sand, say 1 cwt. of sulphate of ammonia, 1 cwt. sulphate of iron and 4 cwt. of dry soil or sharp sand per acre. The immediate effect may be some temporary injury to the grass, but there will be general encouragement of grasses and depression of weeds. On small areas, scorching may be avoided by watering with a hose after the dressing has been given, or by applying the sulphate of ammonia and sulphate of iron in the form of a solution. With a repetition of the process monthly between April and September, combined with the use of other suitable fertilizers and of lime, in association with close mowing, lawns, tennis courts, bowling greens and golf greens may be very greatly improved, fine grass being mainly encouraged. It should be noted that the method of application must depend somewhat upon the area involved, while the composition of the mixture required depends upon the object in view and the type of herbage under treatment, *e.g.*, the fescue seaside golf courses should receive more sulphate of iron than is needed by inland *Agrostis-Poa* turf."*

It may be said that for small areas of lawn, etc., it may be very convenient to use a purchased "lawn sand" and use it as advised by the maker. On the field scale—*e.g.*, golf courses—or for extensive areas of lawns that it is particularly desired to keep in fine condition, it will be better to make up a mixture.

* *Long, H. C.* "Weeds of Grass Land," Bul. No. 41, Min. Agric. and Fisheries, 1932.

Nitric Acid.—Nitric acid is seldom used as a weed killer, but over 100 experiments have been made in Norway* among spring cereals (wheat, barley, oats) with strengths and quantities of solution corresponding to those used for sulphuric acid. Nitric acid destroyed 73 per cent. of the weeds present, and a substantial increase of crop was obtained, the results being somewhat lower than those with sulphuric acid (see Tables p. 3). In some cases a manurial effect of the nitric acid was observed.

Under ordinary circumstances in this country it is unlikely that nitric acid would be selected for weed killing, but if employed the usual precautions for the handling of strong corrosive acids must be observed and care taken for very thorough washing of the spraying machines.

Carbolic Acid.—As a general spray this is expensive and not very effective. Couch Grass may be temporarily injured by heavy spraying with carbolic acid, but the fluid does not penetrate well, and the treated plants usually recover. A mixture of one part of the acid to 4 parts of water has been tried against Creeping Thistle ; when used as a spray it is of little use, but when applied at the base of the plants the creeping underground stems may be killed for 8 or 10 in., though they are apt to sprout again from below the injured parts.† Arable land at Woburn heavily infested with Wild Onion was sprayed with a 5 per cent. carbolic acid solution, which reduced the weed without effectively destroying it, but the treatment did not damage the soil for future cereal crops.‡ Attempts to destroy weeds on paths, at the rate of 2 gal. of 1 per cent. solution per 100 sq. ft., were negative, but possibly the quantity used was too small.§ Altogether carbolic acid does not seem to be very promising as a weed killer.

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* *Korsmo, E.* (1932.) Undersøkelser 1916–1923. p. 382. See ref. * p. 3

† *Pammel, L. H., and King, C. M.* (1909.) "Notes on Eradication of Weeds, with Experiments made in 1907 and 1908." Iowa State Coll. Expt. Stat., Bull. 105, pp. 281–282.

‡ *Voelcker, J. A.* (1911.) "The Eradication of Wild Onion." *Jour. Roy. Agric. Soc.*, 72, pp. 404–9.

§ *Hill, A.* (1928.) "Trials of Weed-Killers on Garden Paths at Craibstone." North Scot. Coll. Agric. Reprinted from *Scot. Jour. Agric.*, XI, No. 2, p. 3.

Hydrochloric Acid.—This has been tried in France against Wild Radish, but the results were so unequal and uncertain that it cannot be recommended for use as a weed spray. Heavy applications of weak solutions of hydrochloric acid, however, will kill weeds and also insects, such as ants, on uncropped areas. The effects of such treatment are said to persist for some time because the acid gives rise in the soil to compounds that hinder vegetation from reasserting itself.

Nickel Sulphate.—The action of nickel sulphate was compared with that of copper sulphate on a small scale at Rothamsted. The nickel sulphate killed Charlock plants when they were just coming into flower, but its action was rather slower than that of copper sulphate, as six days elapsed before the plants were quite dead after treatment with a 3 per cent. solution. A double strength solution acted more quickly. The result was promising enough to suggest that nickel sulphate might be used effectively if it were produced sufficiently cheaply, though possibly stronger solutions might be needed than with copper sulphate.

Copper Nitrate.—Copper nitrate spray has been found to kill young plants of Charlock, as well as Sorrel, Chickweed and Wild Vetch, Poppy also being severely injured. The effect on the crop is to kill lucerne and sainfoin, while red clover, spinach and oats are very little affected.

Heavy infestations of Dandelion on grass land have been controlled, though not eradicated, by spraying with 2 per cent. copper nitrate solution at the rate of 200 gal. per acre,* two applications, in July and August, being given. On lawns, treatment with sulphate of ammonia after spraying enhances the beneficial effect.

Chloride and carbonate of copper have also been tried as weed killers, with a certain degree of success, but they are not so effective as copper sulphate, and are unlikely to be used in place of it.

Carbon Bisulphide.—Carbon bisulphide is a highly inflammable and explosive compound, giving off fumes that are

* *McRostie, G. P., and Silversides, W. H.* (1936.) Dandelion Eradication. *North-west Grain Dealers' Association,* Pamphlet No. 8, pp. 1-4. See also (1940) *Sci. Agric.,* XX, pp. 419-23.

harmful to human beings if inhaled in any quantity. Great care must be taken to keep it away from any flame, and if any remains in an open container it should be covered with a layer of water to hinder the production of inflammable fumes. It is not in general use as a weed killer, but has proved very valuable in reducing stubborn areas of perennial weeds. Incidentally, it is much used as a poison for killing insect pests in the soil.

Carbon bisulphide is not used as a spray, but is inserted directly into the soil.* Holes are bored 2 ft. apart, about 18 in. deep on light soil and 2 ft. deep on heavy land, and a measured quantity of about 2 oz. of the liquid poured into each, the holes being plugged with soil to prevent loss by evaporation. The poison rapidly penetrates through the soil, killing the underground parts of perennial weeds. Wild Convolvulus can readily be reduced in this way, and in parts of America where this weed is rampant the cost of the treatment is stated to be repaid by its successful results.

Dandelions on lawns can also be killed by pouring about a teaspoonful of carbon bisulphide into the crown of each plant. This can most conveniently and safely be done by the use of a mechanic's oil can, which applies the poison to the right spot and minimizes the production of noxious fumes.

Tetrachlorethane.—This has been successfully used for the control of Bindweed (*Convolvulus arvensis*) by placing 2 oz. of tetrachlorethane in holes 18 in. deep and 18 in. apart, a single application giving complete eradication in the area concerned.†

Ammonium Thiocyanate.—Various by-products from coal-gas works are of agricultural value because they will destroy weeds and at the same time benefit grasses on pastures and meadows. The chief of these by-products are gas liquor and spent oxide. The latter has been used at the rate of ½ ton per acre,‡ the active constituent being the ammonium thiocyanate it contains. In New Zealand 2½ per cent. solutions at 200 gal.

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* *Rogers, C. F., and Hatfield, I.* (1929.) Carbon Disulphide for the Eradication of Perennial Weeds. *Colorado Expt. Sta.*, Bull. 347, pp. 5–23.

† *Bakke, A. L.* (1941.) The Use of Tetrachlorethane in the Eradication of the European Bindweed. *Iowa Acad. Sci.*, 48, pp. 192.

‡ *Aston, B. C., and Bruce, J. A.* (1933.) "The Chemistry of Weed-killers." *N.Z. Jour. Agric.*, Vol. 46, No. 2, pp. 108–109.

per acre have been used to eradicate Ragwort from pastures.* Stronger solutions gave more effective control, but the temporary scorching of the grass was more severe and persisted longer before recovery. On bare land, not carrying a crop, thiocyanate may be very effective. In America heavy doses of 10 lb. per sq, rod killed all weeds, but also sterilized the soil for at least four months.† With 2 lb. per sq, rod most of the weeds were killed, but the land was fit for cropping about two or four weeks later and the leaves of the plants were deep green, possibly from the extra nitrogen supplied by the thiocyanate.

A double action occurs with this weed killer. When sprayed on to the plants in solutions containing from 1 to 5 lb. per gal. the leaves are rapidly discoloured and killed. If the thiocyanate is washed into the soil by rain it then acts as a poison absorbed by the roots, and further damage is done. Large isolated weeds such as Burdock may be killed by the application of dry ammonium thiocyanate to the soil round the base of the stem, the dose varying according to the size of the plant. A large seedling Burdock 4 ft. high would need a teaspoonful of thiocyanate to destroy it.

A liquor containing tarry residues in addition to ammonium thiocyanate has been found to give better results than solutions of the pure thiocyanate, as the effect is more lasting.

Potassium Chloride.—This potash fertilizer will kill Charlock when used as a spray of 20 to 30 per cent. strength, the quantity required per acre depending on the degree of weed infestation; about 300 lb. per acre has been recommended. Cereals are not damaged by it, and on land needing potash the manurial after-effect of the spraying is very beneficial. The disadvantage lies in the cost, but if potassium chloride were obtainable cheaply it would be well worth a trial.

Washing Soda.—Red Sorrel and young plants of Chickweed have been killed by 70 gal. per acre of a 10 per cent. solution of washing soda, Poppies being uninjured, and Wild

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* *Aston, B. C., and Bruce, J. A.* (1933.) "The Chemistry of Weed-killers." *N.Z. Jour. Agric.*, Vol. 47, No. 1, pp. 4-7.

Aston, B. C., Bruce, J. A., and Thompson, J. B. (1935.) The Chemistry of Weed-killers—Thiocyanates. *N.Z. Jour. Agric.*, Vol. L, pp. 164-72.

† *Harvey, R. B.* (1931.) "Ammonium Thiocyanate as a Weed Eradicant." *Amer. Soc. Agron.*, Vol. 23, pp. 944-946.

Vetch and other weeds receiving little damage. The crops of red clover and spinach were not affected.

Washing soda was not effective as a weed killer on garden paths when used as a 5 per cent. solution at the rate of 2 gal. per 100 sq, ft.* An additional dressing proved useless, and the treated area became more heavily infested with weeds as time went on. Possibly the concentration of the solution was insufficient and greater strengths might have proved more successful.

Caustic Soda (Sodium Hydrate).—Caustic soda is likely to damage all vegetation, and its use is, therefore, limited to destroying weeds on waste ground or on areas that can remain uncropped until the chemical has been washed out of the soil by rain. Where Blackberry is troublesome it may be cleared by cutting down the old dry stems and spraying the new growth at intervals with caustic soda solution, at the rate of 2 lb. to 4 gal. of water.

Bisulphate of Sodium.—This product can sometimes be obtained cheaply and acts efficiently as a weed killer, although it is somewhat difficult to handle. French experiments with 20 per cent. solutions among cereals have shown that Charlock is killed at all stages of growth† ; other recommendations are 80 gal. per acre of a 45 per cent. solution (360 lb. per acre of bisulphate)‡ when the weeds are very abundant. The action is similar to that of sulphuric acid spray. It is also effective in destroying the more or less aquatic weeds that obstruct irrigation channels in certain regions, for which purpose it can be used either in solution or as a powder. In the same way it might prove useful in clearing drainage ditches where they tend to become choked with vegetation.

A similar compound, potassium bisulphate, as a 14 per cent. solution at the rate of 80 gal. per acre will kill Charlock and Annual Sowthistle, though it hardly affects Poppies, but at this strength of application barley is badly injured.

* *Hill, A.* (1928.) "Trials of Weed Killers on Garden Paths." *Scot. Jour. Agric.*, XI, No. 2, pp. 1-6.

† *Raybaud, L., and Dupont, G.* "Action du Bisulfate de Sodium sur les Végétaux." *Rev. Gen. Bot.*, 38, pp. 707-719.

‡ (1919.) Feuille d'information du Ministère de l'Agriculture, XXIII, No. 8.

Boron Compounds.—Attempts have been made to utilize boron compounds for weed control, as they are toxic to many plant species, and there is no fire hazard as occurs with chlorates.* The results hitherto have been so uncertain that the materials cannot be generally recommended for this purpose. Plant species vary much in susceptibility, and the poisonous action of boron compounds also varies with soil type, rainfall, and method of application. Generally 200 lb. or more of borax per acre have been found to be lethal. Some workers claim that the material loses its potency soon after application, as part is leached out and part is fixed by the soil, whereas others state that boron is much more stable in the soil and its effect much more lasting.†

Oils.—Comparatively little is known as to the properties of oil as a weed killer in this country. Distinction must be drawn between crude petroleum oil and oil of a lighter type, such as kerosene and orchard heating oil, since the action and after-effects are not necessarily the same. When sprayed on vegetation oil kills crop and weeds alike, and, therefore, it can only be used as a weed killer when there is no crop to be considered. Crude oil affects the soil rather seriously and hinders the germination of seeds for some long time after application. Consequently, the crude oil is of little use on cropped areas, but is very effective in keeping down weeds on paths and waste ground. Orchard heating oil (used for making " smudges " in orchards in time of frost), on the other hand, kills the weeds, but has little after-effect on the soil, and if spraying is done early in the year a late crop can be grown satisfactorily.

In Indiana, U.S.A., orchard heating oil was most successfully used for eradicating Wild Onion,‡ which infested the arable land over large areas. The weeds were sprayed in the tender leaf stage, before they began to form heads, about the end of April, at least 75 gal. per acre being used. The area was left

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* *Crafts, A. S., Brice, H. D., and Raynor, R. N.* (1941.) Plot Tests with Chemical Soil Sterilants in California. *Calif. Agric. Expt. Sta.*, Bull. 648, pp. 3-25.

† *Curtis, A. L.* (1937.) About Borax, Boric Acid, and their Less Known Applications. Sands, Clays and Minerals, 3, pp. 115-8.

‡ *Pipal, F. J.* (1914.) "Wild Garlic and its Eradication." Purdue Agric. Expt. Sta., Bull. 176, Vol. XVIII, pp. 5-43.

untouched for three or four weeks, by which time the bulbs had thoroughly rotted, and the land was then ploughed and sown with a late crop. A certain number of bulbs lying dormant in the soil escaped the first spraying and grew out the following spring, when they were dealt with as before. Where only a few Wild Onion plants were present, it was found that kerosene oil was effective, either applied as a spray or with a sprinkling can, care being taken to soak the plants thoroughly. Many other weeds, chiefly annuals, were destroyed by the orchard heating oil, but its ultimate effect on Thistles and similar perennials was not determined. With Sheep's Sorrel, however, a single application destroyed all top growth and part of the root stocks, and a second would probably have exterminated the plants.* Where patches of the Sorrel need cleaning out without regard to any other vegetation growing among them this method might be well worth a trial, especially as the oil does not damage the soil and is not poisonous in any way to live stock.

Dandelion and Broad-leaved Plantain in lawns can be killed by the application of a teaspoonful or less of kerosene or good furfural-petroleum combinations poured into the heart of each plant. In Illinois† broadcast applications of up to 750 gal. per acre failed to kill all the underground parts of Quackgrass or Field Bindweed, even when the treatment was repeated. The lighter-grade petroleum oils were in all instances more toxic than heavier-grade oils.

At Agassiz, British Columbia, effective control of Dandelions and Ribwort Plantain in lawns was obtained with stove oil applied at the rate of 1 gal. to 200 sq. ft. in the autumn.‡

Where oil is easily obtainable at reasonable rates it might be profitable to test its value for weed killing on areas where the whole of the vegetation may be killed, although the land is required for cultivation at a later date.

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* *Pipal, F. J.* (1916.) "Red Sorrel and its Control." Purdue Agric. Expt. Sta., Bull. 197, Vol. XIX, pp. 3-28.

† *Burckhardt, H. L.* (1936.) Effectiveness of Furfural Petroleum Combinations in Eradicating Certain Noxious Weeds. *Jour. Amer. Soc. Agron.*, XXV, pp. 437-42.

‡ *Woods, J. J.* (1942.) Chemical Weed Control in Lawns. *Sci. Agric.*, XXI, pp. 356-65.

Appendix

WEED CONTROL IN CEREALS BY CHEMICAL METHODS.*

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A very good case can be made out to support the claim that to-day advances in chemical methods of weed control are proceeding more rapidly than those in any other branch of agricultural science. It is not as if this field of research is new, because it is exactly fifty years since Bonnet first demonstrated that yellow charlock could be killed in a cereal crop by spraying with copper sulphate. In spite of the importance of this discovery, initial progress was surprisingly slow. In fact it is true to say that more has been learned about selective weed control in England during the last five years than in the whole of the previous forty-five.

It is perhaps unfortunate that these new advances have not simplified the issues; on the contrary, they have tended to make them more complicated. As regards weeds in cereals the investigations, undertaken with grants from the Agricultural Research Council, confirm that there is no sovereign remedy which will destroy all the common weeds and leave the cereal crop unharmed. Rather have the researches stressed that to give the maximum degree of control a particular herbicide must be chosen according to the dominant weed.

Types of Weed-Killers. At the present time the choice lies between four different types of compounds. Sulphuric acid is now an old stager; nevertheless it still holds its own for the eradication of some kinds of weeds that flourish in cereal crops—chickweed for example. Amongst the many copper compounds tested since 1941, copper chloride has come to the fore; not only is it active at lower concentrations than copper sulphate, but the killing action is much quicker. The need for fine weather is, therefore, less of a hindrance to effective weed destruction.

DNOC Compounds. Dinitro-ortho-cresol compounds, which can for convenience be shortened to DNOC compounds, started off in the last century as organic yellow dyestuffs. Later it was discovered that they possessed insecticidal properties, and finally, in 1932, it was found that they also were capable of selectively destroying annual weeds in cereal crops. Investigations since 1940 point to the importance of choosing the right DNOC compound, since small differences in composition produce surprisingly different results.† For example,

* From *The Journal of the Ministry of Agriculture*, Vol. LIII, No. 2, April, 1946, p. 16, by permission of the Ministry of Agriculture and Fisheries.

† There are a considerable number of proprietary weed-killers of the DNOC type on the market. These vary in composition and concentration and are dispatched as pastes or creams, since they must contain some water to comply with railway transport regulations. As the recommendations made in this article are in terms of the pure substances, farmers are advised, when ordering from the manufacturers, to inquire as to the type of compound and the concentration in the container.

the ammonium salt of DNOC is much more effective than the sodium salt. But if sufficient ammonium sulphate is added to the spray solution to produce a 1 per cent. concentration, then the "activated" sodium DNOC is the equal of ammonium D.N.O.C.

Again DNOC itself—which because it is insoluble in water can be used only as a suspension—is on balance little more effective than either the ammonium DNOC or the activated sodium salt for weed control in *spring-sown cereals.* For annual weed destruction in winter wheat, however, the reverse is true; then ammonium DNOC is preferable, because under the cold conditions attendant on early spring spraying it is more active than the DNOC suspension.

MCPA and DCPA. Some account of the earlier investigations with sulphuric acid, copper chloride and the DNOC compounds has been given in a previous article in *Agriculture*,* but since then there has been a new development. In 1940, Slade, Templeman and Sexton, while investigating the effects of spraying "growth-promoting" substances on cereals, noticed that one substance, normally used to induce cuttings to root quicker, killed some of the annual weeds but not the cereals growing in the experimental pots. It was at once clear that here was a new type of selective weed-killer, and a search was immediately instituted to find more active compounds. By the end of 1942 two new materials had been selected as the most promising. Both are complex organic compounds and have, in consequence, long complicated names—2-methyl-4-chloro-phenoxy-acetic acid and 2:4 di-chloro-phenoxy-acetic acid. These names, however, are unlikely to be remembered, so that the abbreviations MCPA and DCPA can perhaps serve better.†

Since 1943 both these substances have been included in the research programme—first at Imperial College and now at Oxford—in order to compare their efficiency with sulphuric acid, copper chloride and the DNOC compounds. Altogether, over the last three years such comparisons have been carried out on some thirty annual weeds normally found in cereals. From the point of view of weed destruction the results have been highly gratifying, since by choosing the right compound and applying it at the right time and at the optimum concentration, almost all the weeds so far investigated can be killed. But from the viewpoint of simplicity the results leave much to be desired. Some weeds, like yellow charlock and pennycress, can be controlled with all the compounds. At the other end of the scale of susceptibility there may be only one effective compound, and this again may be different for different weeds. For example, white charlock, corn buttercup and shepherd's needle are best destroyed with MCPA or DCPA; whereas for mayweeds, corn marigold, and poppies, the DNOC compounds have the highest efficiency.

Specific Weed Control. An attempt has been made to summarize all the available information in tabular form (p. 79). With the several weed-killers and the many weeds a somewhat formidable array of figures cannot be avoided; it is the only way to present the facts concisely. For each weed species the concentrations of the spray solution likely to give the best degree of control are

* (1944) 51, 88.

† MCPA is the active constituent of "Agroxone," "Methoxone" or "CLC". DCPA is the principle in "Phenoxyl". It is likely that other weed-killers of this type will appear on the market. Farmers are advised to inquire as to the composition and concentration when ordering from the manufacturers. The recommendations made in this article are given in terms of the pure substances.

listed under each compound. The degree of control to be expected with good spraying conditions is indicated by asterisks; the greater the number of asterisks the higher the compound ranks in efficiency to control the weed in question. Weeds resistant to a compound, when sprayed at concentrations which do *not* injure the crop, are indicated by the letter "R". Resistance does not mean that no plants will be killed, but that not enough plants will be killed to make spraying worth while. Where the weeds have waxy leaves it may be necessary to add a wetting agent of the sulphonated oil type to make the spray more effective; this is shown in the Table by the letter "W".

Finally, although nearly three hundred critical experiments, involving thousands of plots, have been carried out during the last five years, it has not yet been possible to establish precisely the correct dose for every weed with every compound. Tentative results have, therefore, been indicated by enclosing the figures in brackets, and where no information is as yet available a question mark has been inserted.

Examination of the Table brings out the importance of choosing the right herbicide for the various weeds. In general, sulphuric acid and DNOC kill a wider range of annual weeds than copper chloride, MCPA and DCPA. From this aspect, therefore, the former are preferable where there is a mixed weed population. But this generalization must not be taken as a hard and fast rule; judgment is needed. It is clear from the Table that if white charlock and pennycress are the principal weeds, then MCPA or DCPA will be the best choice. Again, for a mixed population of poppies and fat hen, DNOC should have preference over sulphuric acid, whereas for yellow charlock and goosefoot the most effective results will be obtained by acid spraying.

Spray at the Right Time. *It cannot be stressed too strongly that the best results are obtained when the weeds are sprayed in the seedling stage.* That is especially true with sulphuric acid, since once the weeds have grown large their resistance increases rapidly, *e.g.*, white charlock and fat hen, mayweeds, corn marigolds, knotgrass, willow weed and chickweed. The remaining compounds have the advantage that the stage of growth does not affect the degree of control to the same extent, but with the weeds instanced early spraying is advised. The later the spraying is left the higher will be the concentration required to get a first-class kill and the longer will the weeds be given a chance to compete with the crop.

It should be noticed that all the weeds listed in the Table are annual weeds, and it must not be inferred that the sprays referred to will kill *perennial* weeds. Of the perennial weeds investigated, such as wild inion, docks and thistles, it was found that although the tops may be badly damaged, the plants tend to regenerate. The effects of MCPA and DCPA are the most drastic, and the larger the shoots at the time of spraying the more striking the result. In these circumstances docks and thistles seldom recover in time to reach the seeding stage before the crop is cut. With thistles, regeneration may be partially suppressed and some, but not all, of the rhizomes killed outright; large dock roots are not killed.

Apart from the stage of growth, weather conditions at the time of spraying annual weeds must be taken into account. Sulphuric acid acts quickly, and on a warm day an hour or two of fine weather suffices. DNOC compounds are on a level with sulphuric acid in this respect; copper chloride is slower and needs

at least three hours without rain unless the weather is very hot. Again, with DNOC spraying the warmer the weather the greater the effect on the weeds. If the temperature is high, the lower concentrations indicated in the Table can be used as long as the weeds are not past the seeding stage.

MCPA and DCPA Dusts. *MCPA and DCPA are quite unlike the other selective weed-killers. They act very slowly and their effectiveness is not dependent upon absorption through the leaves.* This ability to cause slow destruction by root absorption means not only that the efficiency of the application is independent of weather conditions but also that any weed seeds which have germinated and are still *below* the soil surface will be killed too. Thus the risk of a second crop of charlock appearing later in the season is largely eliminated.

Because MCPA and DCPA can act through the roots they can be applied as dusts, and this is a great advantage in districts with poor water supplies. It is clearly out of the question to put on the pure substances at rates as low as 1—2 lb. per acre. As suitable dusting machinery is not generally available, the dusts have been diluted to approximately 1 per cent., so that they can be applied with fertilizer drills as a top dressing. Analysis of nearly 600 reports of the 1945 demonstrations carried out by Technical Development Committees show that dusting requires a higher dosage than spraying to have the same efficiency. For example, in the demonstrations on the charlocks, 2 cwt. of dust per acre (2.2 lb. MCPA per acre) has been equalled in performance by 1 lb. per acre applied as a spray. This difference in undoubtedly due in part to the better distribution of the material by spraying than by fertilizer distributors. Two hundredweights of dust per acre seems to be the minimum quantity than can be spread without undue patchiness ; 1 cwt. of dust is too little.

Selective weed control, viewed as a long-term policy, will ultimately lead to cleaner crops, but from the short-term aspect the immediate return in crop yield is the most important financial consideration. The increases in yield resulting from weed destruction are dependent on a variety of factors—season, soil, kind of weed, degree of infestation, and time of spraying. White charlock is probably the most aggressive weed, and increases in the yield of barley of up to 90 per cent. have been recorded in the present investigations. Over all the experiments in the last three years, irrespective of the kind of annual weed destroyed, the average gain in yield of grain has been 22 per cent.

The net increase in crop yield is a balance between the benefits of the elimination of weed competition and the check caused to the crop by spraying. DNOC compounds, DCPA and MCPA are greatly superior to sulphuric acid in their direct effects on the crop, since at the concentrations recommended in the Table they do not affect grain production. Therefore, for an equivalent kill of weeds, spraying with DNOC compounds or MCPA and DCPA will result in higher yields than acid spraying. In this respect copper chloride is intermediate between sulphuric acid and DNOC: for spring cereals the concentration should not exceed 2 per cent. ; in autumn-sown crops concentrations can be up to 3 per cent. *Never add a wetting agent to copper chloride ; the spray will damage the crop severely.*

Weed Control in Undersown Cereals. So far no mention has been made of the problems of weed control in cereal crops undersown with grasses and clovers. If the " seeds " are sown early so that they come up with the weeds, spraying can in no circumstances be carried out because both the seedling

clovers and the grasses will be killed with the weeds. If the " seeds " have not appeared above ground but the weeds have, than it is safe to use only sulphuric acid or copper chloride.

If the weeds are killed first and the " seeds " sown afterwards, sowing can take place immediately after spraying with sulphuric acid or copper chloride. With DNOC it is necessary to wait at least ten days after spraying before sowing. *The use of DCPA or MCPA is out of the question because residues toxic to germinating " seeds " remain in the soil for at least six weeks.*

On those unfortunate occasions when there is a danger of the weeds smothering the " seeds," spraying should not be attempted until the grasses and clove are past the seeding stage. If the weed is yellow charlock or pennycress, there is a good chance of killing the weed without much damage to the " seeds " by spraying with copper chloride at a 1 per cent. concentration. No alternative spray treatment can at present be recommended.

A Few Words of Warning. Because MCPA and DCPA, and to a less extent DNOC compounds, are so highly active, there is considerable danger of spray or dust " drift " damaging neighbouring crops. Roots, beans, onions, and brassica crops are particularly sensitive to MCPA and DCPA. This possibility of " drift " on to adjoining crops should be avoided by choosing days when there is little wind and spraying or dusting into the wind. It may be advisable to leave a wide " headland " in the cereal crop untreated on the windward side of a susceptible crop.

All spraying should be carried out at 100 gallons per acre; with the existing types of spraying machines, excluding " atomizers," a lower rate of application does not give a good cover. Excessive overlapping should be avoided; it is wasteful, and an overdose of spray or dust on the overlap may check the crop unduly.

Farmers and contractors will be familiar with the precautions needed for handling and mixing acid. Copper chloride, which takes up water rapidly, may be available in the dry state or as concentrated solutions in carboys.* No special precautions are needed in making up the spray, since the material does not harm skin or clothing. *But dilute copper chloride is more corrosive to metals than sulphuric acid. In consequence, it is essential to wash out the sprayer properly immediately after use.*

The DNOC pastes or creams have a tendency to settle in the containers. Before use, therefore, the constitutents must be remixed by shaking and it may be necessary to stir the contents with a metal rod. The ammonium salt is sparingly soluble, so this and the DNOC suspension need thorough mixing with the added water. Bad mixing leads to bad spraying, and bad spraying means patchy weed control.

All DNOC compounds stain the skin, hair and clothing bright yellow. Such staining of the skin is temporary but nevertheless undesirable. Careless handling during mixing or changing nozzles should, and can, be avoided. Too great an absorption through the skin, for example, on contract work, may be harmful. Rubber boots, rubber gloves and dungarees should be worn over old clothes; cotton and, more especially, woollen garments are stained permanently.

Blocked nozzles or pipes must never be freed by sucking or blowing with the mouth, since DNOC compounds are poisonous when swallowed.

* Copper chloride is the active principle in " Raphanit ".

SELECTIVE CONTROL OF ANNUAL WEEDS IN CEREAL CROPS

Relative Efficiency of Different Herbicides.

CONCENTRATIONS OF MATERIAL PER 100 GALLONS OF SPRAY SOLUTION PER ACRE

WEED SPECIES	B.O.V. ACID *gal.*	COPPER CHLORIDE *lb.*	DNOC *lb.*	MCPA *lb.*	DCPA *lb.*
(a) Yellow Charlock	7—10***	10—15***	6—8***	1.0***	1.0***
(b) Pennycress	7***	15***	4—6***	0.75***	(1.0)***
(c) Treacle Mustard	10***	20***	5—7***	1.5***	(1.5)***
(d) White Charlock	13**	20—30**	8**	2.0***	2.0***
(e) Corn Buttercup	13*	R	8*	2.0***	2.0***
(f) Shepherd's Needle	15*	R	8*	2.0***	2.0***
(g) Corn Poppies	R	R	6—8W***	2.0*	(2.0)*
(h) Fat Hen	12W**	R	6—8***	2.0*	(2.0)*
(i) Goosefoot or Orache	12W**	R	6—8***	2.0*	(2.0)*
(j) Mayweeds	13W*	R	6—8***	R	R
(k) Chamimile	13W*	R	6—8***	R	R
(l) Corn Marigold	13W*	R	8W***	R	R
(m) Cleavers	10***	20—30*	6—8**	R	R
(n) Knotgrass	13W***	R	8*	R	R
(o) Willow Weed	13W**	20—30*	8*	R	R
(p) Hemp Nettle	10***	20—30**	6—8***	(2.0)**	?
(q) Annual Nettle	10W***	(R)	6—8**	(2.0)*	?
(r) Spurrey	10***	20*	6—8W**	2.0*	?
(s) Speedwells	10***	20**	6—8**	R	?
(t) Bearbind	10***	20—30***	6—8**	2.0*	2.0*
(u) Chickweed	13**	R	8*	R	R
(v) Cornflower	(13W)*	R	(8W)**	(2.0)***	?
(w) Parsley Piert	(13W)***	R	(5—7)***	R	?
(x) Fumitory	R	R	6—8W***	R	(R)
(y) Shepherd's Purse	10W***	(30)**	7**	(2.0)*	?

*** = over 90% kill expected. ** over 80%, * over 50%.
R = weed resistant.
W = wetting agent should be added to spray solution.
( ) = figures are tentative.
? = information is not yet available.

(a) *Brassica arvensis.* (b) *Thlaspi arvense.* (c) *Erysimum cheiranthoides.* (d) *Raphanus raphanistrum.* (e) *Ranunculus arvensis.* (f) *Scandix pecten-veneris.* (g) *Papaver rhoeas.* (h) *Chenopodium album, C. ficifolium.* (i) *Atriplex patula, A. hastata.* (j) *Anthemis inodora, A. cotula.* (k) *Matricaria chamomilla.* (l) *Chrysanthemum segetum.* (m) *Galium aparine.* (n) *Polygonum aviculare.* (o) *Polygonum persicaria.* (p) *Galeopsis tetrahit.* (q) *Urtica urens.* (r) *Spergula arvensis.* (s) *Veronica hederaefolia, V. agrestis.* (t) *Polygonum convolvulus.* (u) *Stellaria media.* (v) *Centaurea cyanus.* (w) *Alchemilla arvensis.* (x) *Fumaria officinalis.* (y) *Capsella bursa pastoris.*

DNOC compounds are not corrosive to metals; nevertheless the machine should be washed out and the outside hosed down. An accumulation of dried spray—especially the sodium salt—is liable to a fire risk. Again because of the fire hazard, half-used containers of DNOC should not be left open to dry out. Similarly, clothing saturated with spray should be washed before drying.

MCPA and DCPA are not injurious to men or animals, nor are they corrosive to machinery or clothing, but because of their powerful medicated smell they should be stored away from foodstuffs and grain.

This article has been concerned with the technique of selective weed control in cereal crops. The recommendations made are specific, and if they are applied to weed destruction in other crops the results may be disastrous. For onion and leek crops farmers should use only sulphuric acid. Grasses grown for seed production must not be sprayed until the plants are fully established, and copper chloride should not be used. Even with sulphuric acid, DNOC, MCPA and DCPA, further research is needed to determine their exact effects on grasses. Spraying peas with DNOC compounds is very risky; more often than not both the weeds and the peas will be killed. No methods for weed control in root or brassica crops have yet been evolved.

This year may be the jubilee as regards research work on selective weed control, but there is still much to learn in spite of recent progress.

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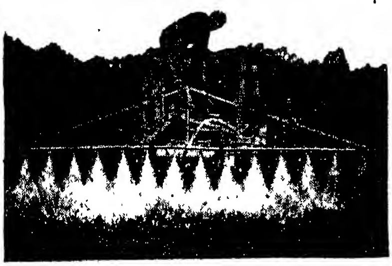

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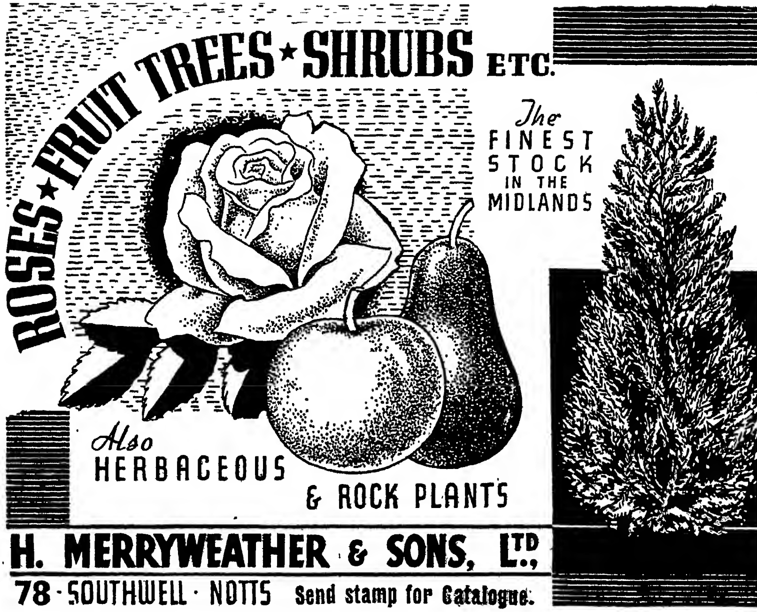
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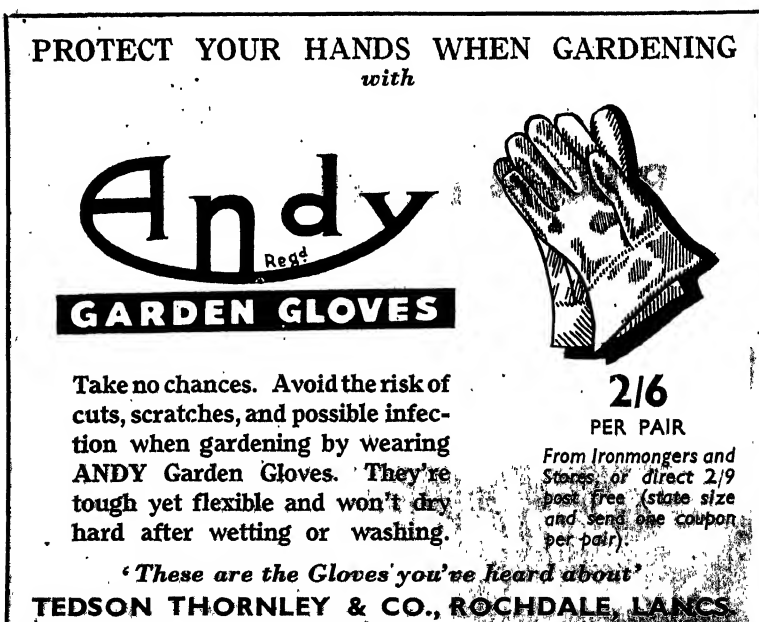
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